

Prepared in cooperation with the Federal Emergency Management Agency

FLOOD OF JULY 12-13, 2004, BURLINGTON AND CAMDEN COUNTIES, SOUTH-CENTRAL NEW JERSEY



Scientific Investigations Report 2006-5096

FLOOD OF JULY 12-13, 2004, BURLINGTON AND CAMDEN COUNTIES, SOUTH-CENTRAL NEW JERSEY

By Amy R. Protz and Timothy J. Reed

Prepared in cooperation with the Federal Emergency Management Agency

Scientific Investigations Report 2006-5096

**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia: 2006

For product and ordering information:
World Wide Web: <http://www.usgs.gov/pubprod>
Telephone: 1-888-ASK-USGS

For more information on the USGS--the Federal source for science about the Earth, its natural and living resources,
natural hazards, and the environment:
World Wide Web: <http://www.usgs.gov>
Telephone: 1-888-ASK-USGS

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the
U.S. Government.

Although this report is in the public domain, permission must be secured from the individual copyright owners to
reproduce any copyrighted materials contained within this report.

Contents

| | |
|--|----|
| Abstract..... | 1 |
| Introduction..... | 1 |
| Purpose and scope..... | 3 |
| Study Area..... | 3 |
| Conditions During Flood..... | 3 |
| Precipitation..... | 3 |
| Dams..... | 6 |
| Flood peaks..... | 8 |
| Datums..... | 8 |
| Peak elevations..... | 8 |
| Peak flows..... | 10 |
| Flood extent..... | 16 |
| Ancillary hydrologic components..... | 21 |
| Effects of tides..... | 21 |
| Ground-water conditions..... | 22 |
| Historical Context..... | 24 |
| Flood Damage..... | 25 |
| Flood Management Upgrades..... | 25 |
| Summary..... | 25 |
| Acknowledgments..... | 26 |
| References Cited..... | 26 |
| Appendix 1. Stream reaches in the study area..... | 29 |
| Appendix 2—Selected photographs of high-water marks and post-flood stream conditions in the study area..... | 61 |

Figures

1-4. Maps showing—

1. Stream reaches and basins in which flood elevations and discharges were determined for the Burlington and Camden Counties, New Jersey, flood of July 12-13, 2004.....2
2. Study area of the July 12-13, 2004, flood with locations of compromised dams, precipitation gages, continuous-record surface-water and tide gages, and observation wells in Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey.....4
3. Land use in Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey.....5
4. Combined radar and precipitation data for Burlington County, New Jersey, July 12, 2004.....6

| | | |
|----|---|----|
| 5. | Hydrographs showing treamflow at six continuous-record stream gages within the Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey, July 10-17, 2004..... | 17 |
| 6. | Map showing stream gages and flood frequencies of peak discharge from July 12-13, 2004, south-central New Jersey | 18 |
| 7. | Hydrographs showing streamflow at 10 continuous-record stream gages surrounding the Rancocas Creek, Cooper River, and Pennauken Creek Basins, south-central New Jersey, July 10-17, 2004..... | 21 |
| 8. | Graph showing tide cycles on the Delaware River and stream elevations on the North and South Branches of the Rancocas Creek at Pemberton and Vincentown, New Jersey, July 10-17, 2004..... | 22 |
| 9. | Graph showing water levels in three wells in the Rancocas Creek Basin, New Jersey, July 1-31, 2004..... | 23 |

Tables

| | | |
|----|---|----|
| 1. | Precipitation totals at rain gages in southern New Jersey and Philadelphia, Pennsylvania, July 12-13, 2004 | 7 |
| 2. | Damaged and failed dams in Burlington County, south-central New Jersey, during July 12-13, 2004, flood. | 9 |
| 3. | Peak stream elevations at 56 sites in Burlington and Camden Counties, south-central New Jersey, during the July 12-13, 2004, flood. | 11 |
| 4. | Historical peak streamflow and peak stream elevations and those recorded during the July 12-13, 2004, flood at U.S. Geological Survey (USGS) continuous-record stream gages and crest-stage gages in Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey..... | 15 |
| 5. | Historical flood peaks and peaks during the July 12-13, 2004, flood at U.S. Geological Survey (USGS) stream gages outside the Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey..... | 19 |
| 6. | Peak stream elevations and flows on the North Branch Rancocas Creek at Pemberton, New Jersey, for four major floods..... | 24 |
| 7. | Peak stream elevations on the Rancocas Creek, south-central New Jersey, September 1, 1940, and July 12-13, 2004..... | 24 |

Conversion Factors and Datum

| Multiply | By | To obtain |
|--|----------|---|
| Length | | |
| inch (in.) | 2.54 | centimeter (cm) |
| inch (in.) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| Area | | |
| acre | 0.4047 | hectare (ha) |
| acre | 0.004047 | square kilometer (km ²) |
| Volume | | |
| cubic foot (ft ³) | 28.32 | cubic decimeter (dm ³) |
| cubic foot (ft ³) | 0.02832 | cubic meter (m ³) |
| Flow rate | | |
| cubic foot per second (ft ³ /s) | 0.02832 | cubic meter per second (m ³ /s) |
| cubic foot per second per square mile [(ft ³ /s)/mi ²] | 0.01093 | cubic meter per second per square kilometer [(m ³ /s)/km ²] |

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29) and North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83), unless otherwise noted.

Flood of July 12-13, 2004, Burlington and Camden Counties, South-Central New Jersey

By Amy R. Protz and Timothy J. Reed

Abstract

Intense rainfall inundated south-central New Jersey on July 12-13, 2004, causing major flooding with heavy property, road, and bridge damage in Burlington and Camden Counties. Forty-five dams were topped or damaged, or failed completely. The affected areas were in the Rancocas Creek, Cooper River, and Pennsauken Creek Basins.

The U.S. Geological Survey (USGS) documented peak stream elevations and flows at 56 selected sites within the affected area. With rainfall totals averaging more than 6 inches throughout the three basins, peak-of-record flood elevations and streamflows occurred at all but one USGS stream gage, where the previous record was tied. Flood-frequency recurrence-intervals ranged from 30 to greater than 100 years and maximum streamflow per square mile ranged from 13.9 to 263 cubic feet per second per square mile ($\text{ft}^3/\text{s}/\text{mi}^2$).

Peak streamflow at USGS stream gages surrounding the affected basins are associated with considerably lower recurrence intervals and demonstrate the limited extent of the flood. A high tide of about 1 foot above monthly mean high tide did not contribute to high-water conditions. Low ground-water levels prior to the rainfall helped to mitigate flooding in the affected basins. Compared with historical floods in the Rancocas Creek Basin during 1938-40, the July 2004 flood had greater streamflow, but lower stream elevations.

Property damage from the event was estimated at \$50 million. Governor James E. McGreevy declared a State of Emergency in Burlington and Camden Counties on July 13, 2004. After assessment of the damage by the Federal Emergency Management Agency (FEMA), President George W. Bush declared Burlington and Camden Counties disaster areas on July 16, 2004.

Introduction

At the beginning of July 2004, streamflow in Burlington and Camden Counties, New Jersey, was at base-flow condi-

tions (no runoff from precipitation) (fig.1). During July 5 and 6, streamflow increased slightly in response to less than an inch of rain, then returned to base-flow conditions by July 7. Precipitation during July 12 and 13, 2004, produced the largest documented flood in the area since 1940.

A low-pressure system developed along a warm front that stalled over south-central New Jersey, resulting in torrential rains on July 12-13, 2004. As much as 13.2 inches of rain fell at rates of more than 3 inches per hour in some areas. Consequent flooding occurred in the basins of Rancocas Creek, Cooper River, and Pennsauken Creek, which are tributaries to the Delaware River (fig. 1). Concurrent with the heavy rains, 28 dams were damaged, and 17 dams failed completely. All of these dams were along streams in the Rancocas Creek Basin, with the exception of a dam that was damaged in the Batsto River Basin. After the dams failed, several of the impounded lakes were reduced to the streams that they once had been.

Streamflow, precipitation, tidal, and ground-water data were available on a near real-time basis through the U.S. Geological Survey (USGS) New Jersey Water Science Center (NJWSC) website, <http://nj.usgs.gov>, so that hydrologic conditions could be monitored during the event. The near real-time streamflow data were useful to the USGS in deciding where field-data collection would be most beneficial. The website also was accessible to other agencies and the public for various flood-related decisions.

The USGS, in cooperation with the Federal Emergency Management Agency (FEMA), conducted a study to collect, compute, and compile flood-related data in the three affected basins subsequent to the event. Peak stream elevations were determined at 56 study sites, and peak streamflows were determined at 9 of the 56 sites. Precipitation values were collected from two precipitation gages operated by the USGS. In addition, precipitation totals were collected at 38 locations by the National Weather Service. A list of compromised dams was obtained from the New Jersey Department of Environmental Protection Bureau of Dam Safety and Flood Control. These data, obtained during or shortly after the precipitation, are assembled herein to provide a detailed account of the flood.

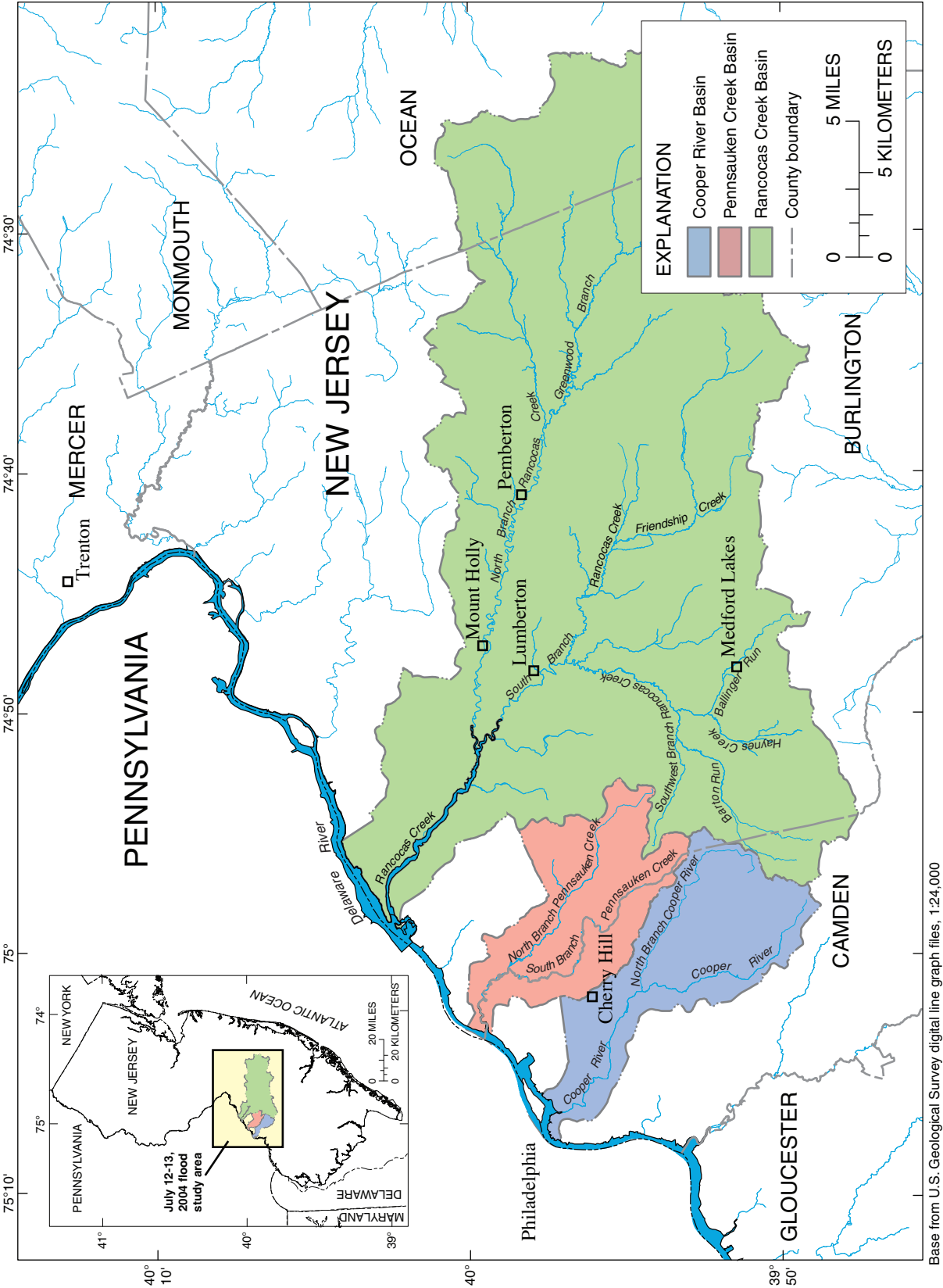


Figure 1. Index map of stream reaches and basins in which flood elevations and discharges were determined for the Burlington and Camden Counties, New Jersey, flood of July 12-13, 2004.

Purpose and scope

This report documents the precipitation, peak stream-flows, and stream elevations determined for the Rancocas Creek, Cooper River, and Pennsauken Creek Basins resulting from the storm of July 12-13, 2004. Dam failures, flood-frequency recurrence intervals, maximum discharge per square mile, tidal effect, ground-water conditions, flood damage in the three basins, and peak elevations and flows at USGS stream gages outside the affected area also are described.

Study Area

Flood data were collected in south-central New Jersey within Burlington and Camden Counties at a total of 56 locations on 12 stream reaches. The sites include 6 continuous-record USGS stream gages and 50 ancillary sites, several of which are USGS partial-record sites. The ancillary sites were chosen by Surface-Water Specialist Robert D. Schopp of the USGS New Jersey Water Science Center on the basis of hydrologic significance. Forty-two sites are in the Rancocas Creek Basin, 11 sites are in the Cooper River Basin, and 3 sites are in the Pennsauken Creek Basin. All three basins drain into the lower Delaware River. The downstream reaches of each basin are tidally affected. Only the farthest downstream site in the Rancocas Creek Basin is in a tide-affected part of the reach. The locations of study sites, failed and damaged dams, precipitation gages (with precipitation values), tide gages, and ground-water observation wells are shown in figure 2. Detailed maps of individual stream reaches and site descriptions are shown in appendix 1. Dams in the study area that did not sustain any damage are not shown on the maps.

The Rancocas Creek Basin, in Burlington County, has a drainage area of approximately 347 mi². Land use in the Rancocas Creek Basin is 65 percent forests and wetlands, most of which are in the upper reaches of the basin (fig. 3) (New Jersey Department of Environmental Protection, 2000). Urban areas account for approximately 20 percent of the basin, with some development in the upper reaches of the Southwest (SW) Branch Rancocas Creek. The most concentrated urban areas are near the mouth of the Rancocas Creek. Approximately 10 percent of the basin is used for agriculture, which is concentrated near the center of the basin. Study sites within the Rancocas Creek Basin are on the South Branch Rancocas Creek, Friendship Creek, Haynes Creek, Southwest Branch Rancocas Creek, Ballinger Run, Barton Run, North Branch Rancocas Creek, and Greenwood Branch (app. 1-1 to 1-9).

Land use in most of the Cooper River Basin, in Camden County, is urban with little forest, wetland, and agricultural areas. At its mouth, the basin receives runoff from an area of approximately 40 mi². Study sites within the Cooper River Basin are on the North Branch Cooper River and Cooper River (app. 1-10 and 1-11).

In the Pennsauken Creek Basin, which spans both Burlington and Camden Counties, land use is mostly urban

with slightly more agricultural and wetland areas than in the Cooper River Basin. At its mouth, the basin receives runoff from an area of approximately 36 mi². Study sites within the Pennsauken Creek Basin are on the North and South Branches of Pennsauken Creek (app. 1-12 and 1-13).

Conditions During Flood

The precipitation leading to and during the flood, the conditions of the dams, stream elevations, and flows during July 12-13, 2004, the extent of the flood, and hydrologic components supplemental to the flood are discussed in the following sections.

Precipitation

Light rain began to fall in south-central New Jersey during the morning hours of July 12, 2004, and became heavier as the day progressed (fig. 4). Torrential downpours ensued in the late afternoon and evening as the result of a warm front that approached from the southwest and stalled over the region as a low pressure system developed along the front. Thunderstorms continually redeveloped over the same area and persisted until late in the day (National Oceanic and Atmospheric Administration, 2005a). The rainfall eventually subsided in the early morning hours of July 13, 2004. The storm was not related to a hurricane and it occurred mainly over Burlington and Camden Counties; the most intense rainfall was recorded in central Burlington County.

The Rancocas Creek Basin received the most rain of the three basins in the study area for July 12-13, 2004 (fig. 4). The maximum recorded rainfall, 13.2 inches, fell in Tabernacle near the upper reaches of Friendship Creek (app. 1-3). The precipitation gage at Tabernacle is not automated, and therefore, the time frame in which the rain accumulated is not certain. An automated precipitation gage at the Greenwood Branch in New Lisbon (GRE1, app. 1-9) recorded a rainfall total of 11.23 inches in 15 ¼ hours. More than 80 percent (9.13 inches) of the total precipitation fell during the 5-hour period from 1730 to 2230 hours, Eastern Daylight Time (EDT), on July 12, 2004, at the New Lisbon gage. The greatest hourly rainfall of 3.51 inches was recorded from 1930 to 2030 hours EDT.

Rainfall totals reported in the Cooper River and Pennsauken Creek Basins were less than those in the Rancocas Creek Basin. The greatest recorded rainfall in the Cooper River Basin was 7.90 inches in Cherry Hill, near a tributary to the Cooper River (app. 1-12). Only one precipitation gage is located in the Pennsauken Creek Basin (app. 1-10). A total of 4.21 inches of rain was reported in Cinnaminson, near the mouth of the Pennsauken Creek (app. 1-11).

Precipitation totals were provided by the National Weather Service, Mount Holly, New Jersey Office. Precipitation totals recorded on July 12-13, 2004, at various locations

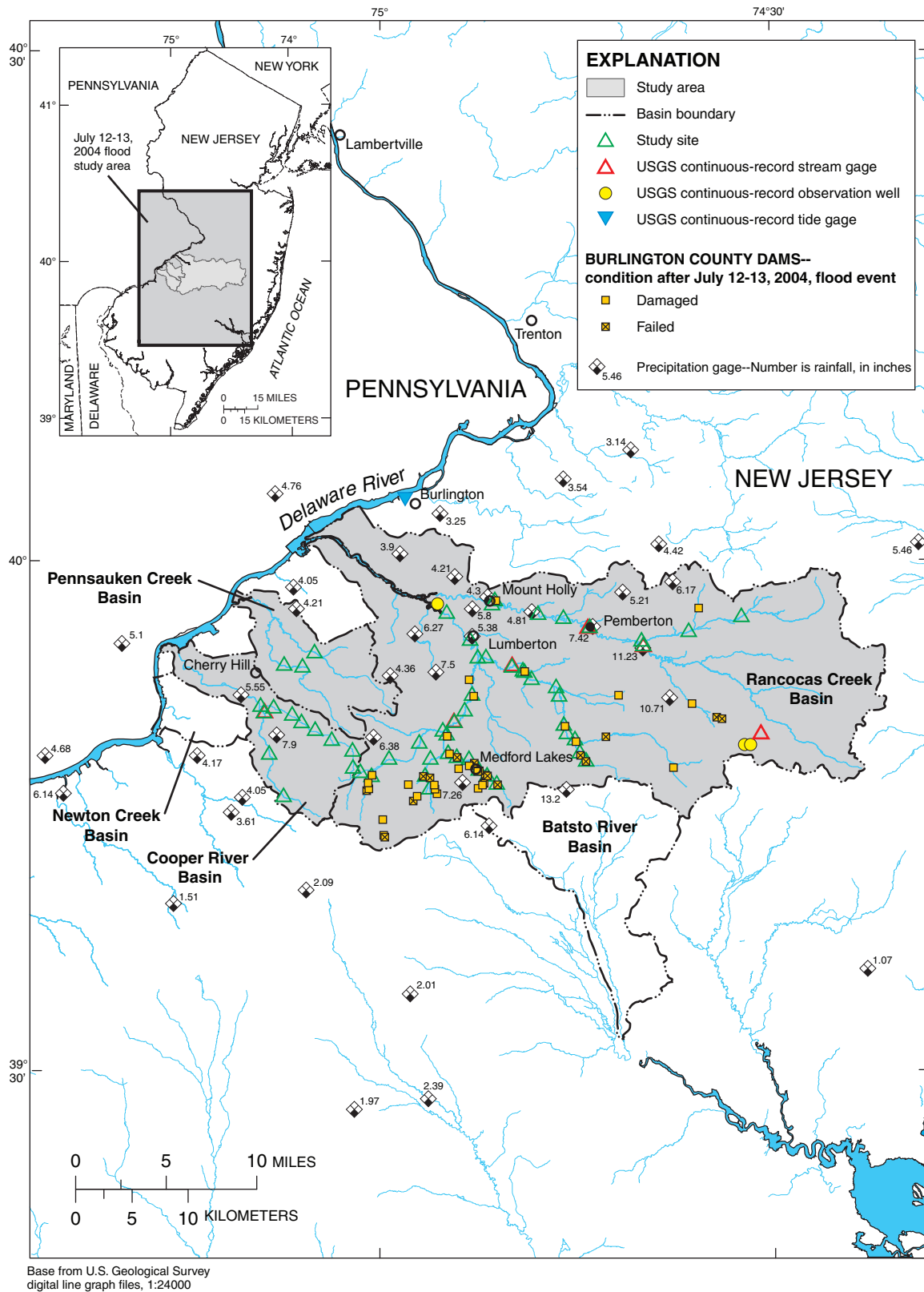


Figure 2. Study area of the July 12-13, 2004, flood with locations of compromised dams, precipitation gages, continuous-record surface-water and tide gages, and observation wells in Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey and vicinity.

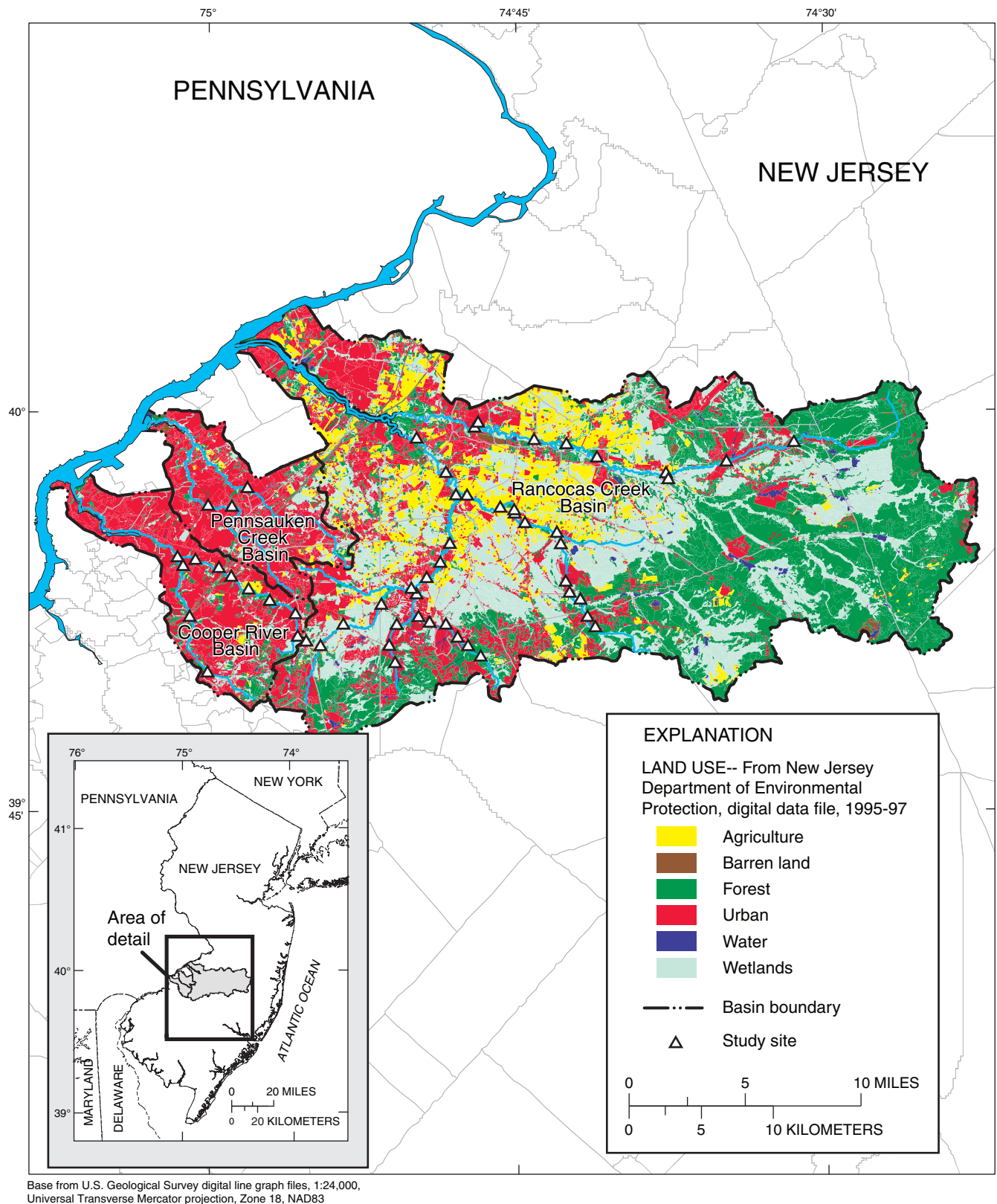


Figure 3. Land use in Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey.

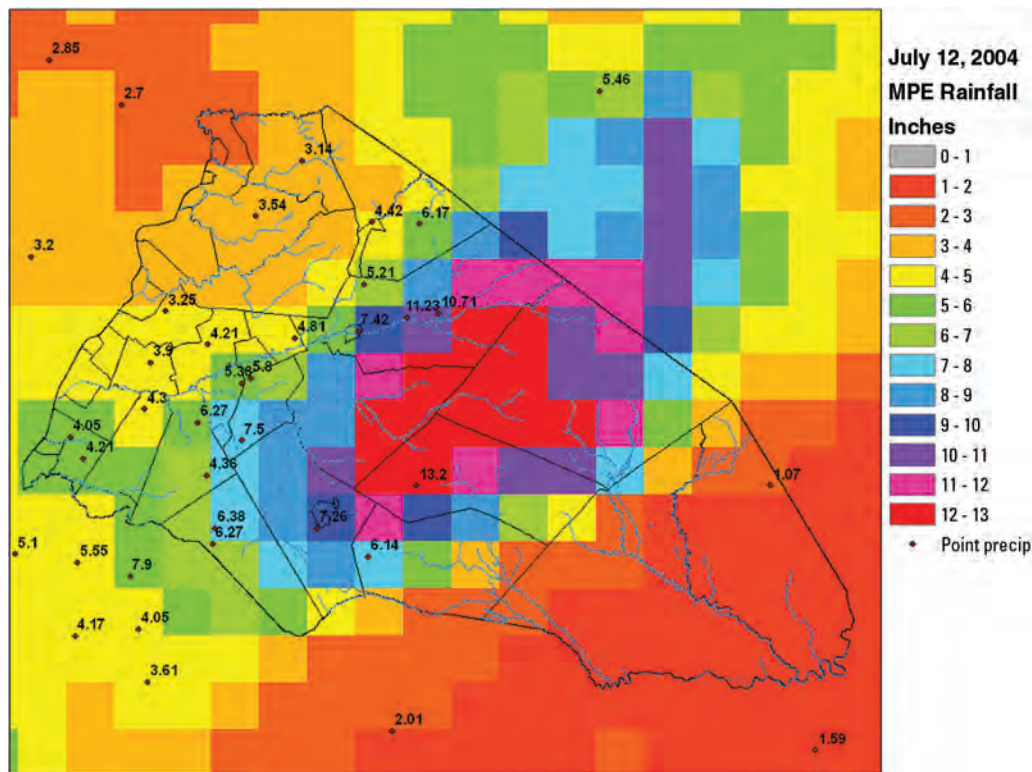


Figure 4. Combined radar and precipitation data for Burlington County, New Jersey, July 12, 2004. (From National Weather Service, Mount Holly Office. Data are not certified; MPE, multiple sensor precipitation estimates; Precip, precipitation, number is rainfall in inches)

in and around the study area are listed in table 1. The rainfall amounts also are presented in figures 2 and 4.

In conjunction with the unusually large amounts of rainfall in south-central New Jersey, the total July 2004 precipitation for the State of New Jersey was 7.30 inches, making this the ninth wettest July from 1895 through 2004 (National Oceanic and Atmospheric Administration, 2005b). The July 2004 total was 2.80 inches greater than the average July rainfall for the period of record. The total precipitation in the preceding 12 months was 50.49 inches, making this the 24th wettest 12-month period since 1895. This total is 5.64 inches greater than the average rainfall for the same 12 months over the period of record. In the month preceding the event, June 2004, total precipitation was 2.84 inches, which ranks as the 79th-wettest June from 1895 through 2004, or 0.90 inches below average for the period of record.

Dams

More than 1,600 dams are present in New Jersey. The many dams that impound water on New Jersey streams provide recreation, public water supply, and flood control, but also create a potential hazard. FEMA categorizes dams into classes to identify the potential threat to life and property from the impounded water.

| | |
|-----------|----------------------------------|
| Class I | (H) High-Hazard Potential |
| Class II | (S) Significant-Hazard Potential |
| Class III | (L) Low-Hazard Potential |

By the end of July 2004, the Bureau of Dam Safety and Flood Control of the New Jersey Department of Environmental Protection (NJDEP) documented that 50 of the 196 high-hazard dams in the state need repair. The Bureau also documented that 317 of the 396 significant-hazard dams in the State need repair. Notable damage to some of these dams occurred as a result of flooding in the last 116 years. Most of this damage likely occurred during flooding in 1889, 1902, 1903, 1940, and 1945 (Ludlum, 1983) and in 1999, 2000, and 2004.

Dam failures resulting from Tropical Storm Floyd in September 1999 and the Sparta Flood of 2000 motivated the inception of a plan by the Bureau of Dam Safety and Flood Control to improve the conditions of dams within the State. In November 2003, voters approved bond funding for the repair of dams, flood-control projects, stream restoration, and dredging. This fund, in which \$95 million was made available, was labeled the “Dam, Lake, Stream, Flood Control, Water Resources, and Wastewater Treatment Project Bond Act of

Table 1. Precipitation totals at rain gages in southern New Jersey and Philadelphia, Pennsylvania, July 12-13, 2004.

[Data provided by National Weather Service (NWS), Mount Holly, New Jersey; ---, none; NAD 83, North American Datum of 1983, USDA, U.S. Department of Agriculture; AHOS, Automatic Hydrological Observing Station; ASOS, Automatic Surface Observing Station.]

| County | NWS Site identifier | Precipitation total (inches) | Name | Municipality, State | Latitude and longitude (NAD 83) | |
|--------------|---------------------|------------------------------|---|----------------------------|---------------------------------|-----------|
| Burlington | TABN4 | 13.20 | Tabernacle | Tabernacle Township, NJ | 39°50'35" | 74°42'28" |
| | NLBN4 | 11.23 | New Lisbon, U.S. Geological Survey | Pemberton Township, NJ | 39°57'22" | 74°37'40" |
| | NLIN4 | 10.71 | New Lisbon Coop | Pemberton Township, NJ | 39°54'58" | 74°35'59" |
| | VAY | 7.50 | Mount Holly | Lumberton Township, NJ | 39°56'13" | 74°50'35" |
| | PMBRT | 7.42 | Pemberton Borough Elementary School | Pemberton Borough, NJ | 39°58'22" | 74°40'48" |
| | MLL014 | 7.26 | Medford Lakes | Medford Township, NJ | 39°50'57" | 74°48'55" |
| | MRLTN | 6.38 | Evesham Township School District | Evesham Township, NJ | 39°53'08" | 74°54'28" |
| | MTLN4 | 6.27 | Mount Laurel | Mount Laurel Township, NJ | 39°58'05" | 74°51'54" |
| | WRI | 6.17 | McGuire Air Force Base | New Hanover Township, NJ | 40°00'32" | 74°35'46" |
| | VCEN4 | 6.14 | National Weather Service Cooperative observer | Shamong Township, NJ | 39°48'52" | 74°47'18" |
| | MTHN4 | 5.80 | Mount Holly | Hainesport Township, NJ | 39°59'17" | 74°48'18" |
| | LMBRT | 5.38 | Lumberton Middle School | Lumberton Township, NJ | 39°57'58" | 74°48'18" |
| | HMBRT | 5.21 | Helen A. Fort Middle School | Pemberton Township, NJ | 40°00'02" | 74°38'56" |
| | DEAN | 4.81 | National Weather Service Employee | Eastampton Township, NJ | 39°59'06" | 74°44'35" |
| | WRIN4 | 4.42 | Wrightstown | Wrightstown Borough, NJ | 40°02'20" | 74°36'36" |
| | MTLR3 | 4.36 | Thomas Harrington Middle School | Mount Laurel Township, NJ | 39°55'59" | 74°53'26" |
| | MNTHL | 4.30 | Sacred Heart School | Mount Holly Township, NJ | 39°59'50" | 74°47'22" |
| | CNNMN | 4.21 | St. Charles Borromeo School | Cinnaminson Township, NJ | 39°59'17" | 74°59'17" |
| | PHIN4 | 4.21 | National Weather Service Forecast Office | Westampton Township, NJ | 40°00'50" | 74°49'23" |
| | CINNM | 4.05 | Eleanor Rush Elementary School | Cinnaminson Township, NJ | 40°00'19" | 74°59'28" |
| | WOODY | 3.90 | National Weather Service Employee | Willingboro Township, NJ | 40°01'53" | 74°52'49" |
| | NONE | 3.54 | Mansfield | Mansfield Township, NJ | 40°05'29" | 74°42'36" |
| | BRLNG | 3.25 | Fountain Woods School | Burlington Township, NJ | 40°03'50" | 74°50'17" |
| | --- | 3.14 | Chesterfield | Chesterfield Township, NJ | 40°06'51" | 74°38'23" |
| | NJANG | 1.07 | New Jersey Air National Guard | Bass River Township, NJ | 39°41'53" | 74°23'45" |
| Camden | CHHN4 | 7.90 | Cherry Hill | Cherry Hill Township, NJ | 39°53'15" | 75°00'32" |
| | CRHN4 | 5.55 | USDA AHOS (Cherry Hill) | Haddon Township, NJ | 39°55'08" | 75°02'46" |
| | BLLMW | 4.17 | Bell Oaks Upper Elementary School | Bellmawr Borough, NJ | 39°52'16" | 75°05'28" |
| | SMDN4 | 4.05 | Chews Landing | Gloucester Township, NJ | 39°50'12" | 75°02'40" |
| | BLCKW | 3.61 | Glenn Landing Middle School | Gloucester Township, NJ | 39°49'31" | 75°03'21" |
| | SLVN4 | 2.09 | USDA AHOS (Erial) | Gloucester Township, NJ | 39°45'47" | 74°58'41" |
| | BLAN4 | 2.01 | Ancora Hospital (Blue Anchor) | Winslow Township, NJ | 39°40'48" | 74°52'12" |
| Gloucester | WDEN4 | 6.14 | Municipal Authority West Deptford | West Deptford Township, NJ | 39°50'24" | 75°13'48" |
| | FLTN4 | 1.97 | USDA AHOS (Piney Hollow) | Franklin Township, NJ | 39°35'15" | 74°55'41" |
| | WSTN4 | 1.51 | USDA AHOS (Bethel Mill Park) | Washington Township, NJ | 39°45'09" | 75°06'57" |
| Ocean | NEL | 5.46 | U.S. Naval Air Station, Lakehurst | Manchester Township, NJ | 40°02'24" | 74°20'24" |
| Atlantic | GEHN4 | 2.39 | U.S. Geological Survey | Folsom Borough, NJ | 39°35'42" | 74°51'05" |
| Philadelphia | PPIP1 | 5.10 | Franklin Institute | Philadelphia, PA | 39°57'36" | 75°10'12" |
| | PNE | 4.76 | ASOS Northeast Philadelphia Airport | Philadelphia, PA | 40°04'48" | 75°00'36" |
| | PHL | 4.68 | ASOS Philadelphia Airport | Philadelphia, PA | 39°52'12" | 75°15'00" |

2003” (New Jersey Department of Environmental Protection, 2005).

The NJDEP reported that 17 dams failed and 28 dams were damaged in Burlington County during the flooding of July 12-13, 2004 (table 2). The locations of these dams are shown in figure 2 and on the individual maps of stream reaches in appendix 1.

All 17 dam failures that occurred during July 12-13, 2004, were in the Rancocas Creek Basin. Two of the dams were in the upper reaches of the North Branch Rancocas Creek Basin, and the remaining 15 were in the upper reaches of the South Branch Rancocas Creek Basin. Of the 28 damaged dams, 27 were in the Rancocas Creek Basin: 3 in the North Branch Rancocas Creek Basin and 24 in the South Branch Rancocas Creek Basin. The remaining damaged dam was in the Batsto River Basin, which is south of the study area. Land use in the Batsto River Basin is mostly forest and wetlands; no significant flooding was reported in that basin (fig. 2).

Flood peaks

Several new peak-of-record stream elevations and flows resulted from the torrential rainfall within the Rancocas Creek, Cooper River, and Pennsauken Creek Basins. The dam breaks in the Rancocas Creek Basin augmented flooding on the South and Southwest Branches of Rancocas Creek.

Peak stream elevations are presented in reference to various datums. Approximately 60 percent of the flood elevations determined in the study area exceeded the FEMA-projected 100-year flood elevations. Of the flows determined in the study area, 50 percent exceeded 100-year recurrence intervals, as determined from historical USGS stream gage data (U.S. Interagency Advisory Committee on Water Data, 1982). Flows were computed using established USGS methods (Benson and Dalrymple, 1967, Hulsing, 1967, Kennedy, 1984, and Matthai, 1967).

Datums

Elevations presented in this report use the following vertical datums:

- **Gage datum** is a horizontal surface used as a zero point for measurement of stage or gage height. This surface usually is located slightly below the lowest point of the stream bottom such that the gage height is usually slightly greater than the maximum depth of water. Because the gage datum itself is not an actual physical object, the datum usually is defined by specifying the elevations of permanent reference marks such as bridge abutments and survey monuments, and the gage is set to agree with the reference marks. Gage datum is a local datum that is maintained independently of any national geodetic datum. However, if the elevation of the gage datum relative to the national datum (North American Vertical Datum of 1988 or

National Geodetic Vertical Datum of 1929) has been determined, then the gage readings can be converted to elevations above the national datum by adding the elevation of the gage datum to the gage reading.

- **National Geodetic Vertical Datum of 1929** (NGVD of 1929) is a fixed reference adopted as a standard geodetic datum for elevations determined by leveling. It was formerly called “Sea Level Datum of 1929” or “mean sea level.” Although the datum was derived from the mean sea level at 26 tide stations, it does not necessarily represent local mean sea level at any particular place. See NOAA web site: <http://www.ngs.noaa.gov/faqs.html#WhatVD29VD88> (See “North American Vertical Datum of 1988”)
- **North American Vertical Datum of 1988** (NAVD 88) is a fixed reference adopted as the official civilian vertical datum for elevations determined by Federal surveying and mapping activities in the United States. This datum was established in 1991 by minimum-constraint adjustment of the Canadian, Mexican, and United States first-order terrestrial leveling networks.

All latitudes and longitudes presented in this report are in the following horizontal datum:

- **North American Datum of 1983** (NAD 83) is the horizontal control datum for the United States, Canada, Mexico, and Central America that is based on the adjustment of 250,000 points including 600 satellite Doppler stations that constrain the system to a geocentric origin. NAD 83 has been officially adopted as the legal horizontal datum for the United States by the Federal Government.

Peak elevations

Peak stream elevations were determined at 56 sites along 12 stream reaches throughout the Rancocas, Cooper, and Pennsauken Basins. For the purpose of this study, the sites were given abbreviated names based on the stream names, and numbered in order of upstream direction along the stream reach. For example, SBR0 is the farthest downstream site on the South Branch Rancocas Creek.

High-water marks found at the sites were flagged and documented, then rated subjectively (as excellent, good, fair, or poor) by USGS personnel. This rating indexes the accuracy of mud, seed, debris, and other physical signs used as indicators of the flood crest. Most of the marks were within 100 feet of the upstream and downstream sides of a bridge or dam at each site. The locations of the measurement sites, as well as the location of high-water marks in reference to the bridge or dam at each site and several photographs, can be found in the appendixes. Six of the sites are located at USGS continuous stream gages. Four of those six sites provided high-water marks to confirm recorded peaks, and to determine the

Table 2. Damaged and failed dams in Burlington County, south-central New Jersey, during July 12-13, 2004, flood.

[Data provided by N.J. Department of Environmental Protection, Bureau of Dam Safety and Flood Control. Class defines hazard potential: H, high; S, significant; L, low; NAD 83, North American Datum of 1983]

| Stream reach | Dam name | Condition | Class | Municipality | Stream | Latitude and longitude (NAD 83) | |
|---------------------------------|-----------------------------|-----------|-------|-----------------------|---|---------------------------------|-----------|
| South Branch Rancocas Creek | New Jersey No Name # 8 Dam | Damaged | L | Southampton Township | South Branch Rancocas Creek | 39°55'02" | 74°39'15" |
| | Vincentown Mill Dam | Damaged | H | Southampton Township | South Branch Rancocas Creek | 39°56'11" | 74°45'07" |
| Friendship Creek | Camp Inawendiwin Middle Dam | Failed | L | Tabernacle Township | Friendship Creek | 39°51'50" | 74°41'13" |
| | Camp Inawendiwin Lower Dam | Failed | S | Tabernacle Township | Friendship Creek | 39°52'09" | 74°41'36" |
| | Sooy Dam | Damaged | L | Woodland Township | South Branch Burrs Mill Brook | 39°51'32" | 74°35'53" |
| | Third Street Dam | Failed | L | Southampton Township | Burrs Mill Brook | 39°53'04" | 74°40'01" |
| | Fisher Pond Dam | Damaged | L | Southampton Township | Friendship Creek | 39°52'49" | 74°41'57" |
| | Old Forge Lake Dam | Damaged | L | Southampton Township | Friendship Creek | 39°53'33" | 74°42'36" |
| Haynes Creek | Marlton Lakes Upper Dam | Damaged | S | Evesham Township | Kettle Run | 39°48'17" | 74°53'55" |
| | Crane Lake Dam | Failed | L | Evesham Township | Kettle Run | 39°48'14" | 74°53'48" |
| | Burnt Bog Dam | Damaged | L | Medford Township | Kettle Run tributary | 39°50'17" | 74°50'36" |
| | Upper Mimosa Dam | Damaged | L | Medford Township | Kettle Run tributary | 39°50'29" | 74°50'43" |
| | Mimosa Lake Dam | Damaged | L | Medford Township | Kettle Run tributary | 39°50'42" | 74°50'45" |
| | Hinchman Dam | Failed | L | Medford Township | Kettle Run tributary | 39°51'04" | 74°50'58" |
| | Kettle Run Road Dam | Damaged | S | Evesham Township | Bethany Hole Run | 39°49'04" | 74°53'56" |
| | Lost Lake Dam #1 | Failed | L | Evesham Township | Bethany Hole Run | 39°49'59" | 74°52'01" |
| | Van Dal Lake Dam | Damaged | L | Evesham Township | Bethany Hole Run | 39°50'10" | 74°51'48" |
| | Golf Course Dam | Damaged | L | Evesham Township | Haynes Creek tributary | 39°50'44" | 74°52'22" |
| | Blue Lake Dam | Failed | L | Medford Township | Kettle Run tributary | 39°51'10" | 74°51'25" |
| | Oliphants Mill Lake Dam | Damaged | L | Medford Township | Haynes Creek | 39°53'04" | 74°49'55" |
| Southwest Branch Rancocas Creek | Kirbys Mill Dam | Damaged | L | Medford Township | Southwest Branch Rancocas Creek | 39°55'00" | 74°48'18" |
| | Fostertown Road Dam | Damaged | S | Medford Township | Southwest Branch Rancocas Creek tributary | 39°55'46" | 74°48'33" |
| Ballinger Run | Squaw Lake Dam | Failed | L | Medford Township | Ballinger (Haynes Creek tributary 3) | 39°50'46" | 74°46'46" |
| | JCC Dam | Damaged | S | Medford Township | Ballinger tributary | 39°50'33" | 74°47'59" |
| | Upper Stokes Dam | Damaged | S | Medford Township | Ballinger tributary | 39°50'45" | 74°47'44" |
| | Stokes-Lower Dam | Failed | S | Medford Township | Ballinger tributary | 39°50'50" | 74°47'38" |
| | Lake Stockwell Dam | Failed | S | Medford Township | Ballinger (Haynes Creek tributary 3) | 39°51'09" | 74°47'23" |
| | Papoose Lake Dam | Failed | S | Medford Township | Ballinger (Haynes Creek tributary 3) | 39°51'14" | 74°47'32" |
| | Upper Aetna Lake Dam | Failed | S | Medford Lakes Borough | Ballinger (Haynes Creek tributary 3) | 39°51'25" | 74°47'55" |
| | Saipe Lake Dam | Damaged | S | Medford Township | Ballinger tributary | 39°51'23" | 74°48'01" |
| | Lower Aetna Lake Dam | Failed | S | Medford Lakes Borough | Ballinger (Haynes Creek tributary 3) | 39°51'48" | 74°48'12" |
| | Quogue Dam | Damaged | L | Medford Lakes Borough | Ballinger tributary | 39°51'39" | 74°48'33" |
| | Cranberry Lakes Dam #6 | Damaged | L | Medford Township | Ballinger tributary | 39°51'30" | 74°49'14" |
| | Birchwood Lake Dam | Failed | S | Medford Township | Ballinger (Haynes Creek tributary 3) | 39°52'03" | 74°49'16" |
| | Timber Lake Dam | Damaged | H | Medford Township | Ballinger (Haynes Creek tributary 3) | 39°52'15" | 74°49'48" |
| Barton Run | Kenilworth #2 Dam | Failed | S | Evesham Township | Barton Run tributary | 39°50'29" | 74°54'57" |
| | Kenilworth #3 Dam | Damaged | L | Evesham Township | Barton Run tributary | 39°50'32" | 74°54'49" |
| | Kenilworth Lake Dam | Damaged | S | Evesham Township | Barton Run tributary | 39°50'46" | 74°54'50" |
| | Union Mill Lake Dam | Damaged | S | Evesham Township | Barton Run tributary | 39°51'10" | 74°54'37" |
| North Branch Rancocas Creek | Bayberry Street Dam | Damaged | L | Pemberton Township | Larkins Run | 39°59'13" | 74°34'14" |
| | Mill Dam | Damaged | L | Mount Holly Township | North Branch Rancocas Creek | 39°59'35" | 74°46'54" |
| Greenwood Branch | Reeves Dam B | Failed | L | Woodland Township | Cooper Branch | 39°53'53" | 74°32'46" |
| | Lower Reeves Bog Dam | Failed | L | Woodland Township | Cooper Branch | 39°53'59" | 74°33'06" |
| | Lebanon Forest #1 Dam | Damaged | S | Pemberton Township | Bisphams Mill Creek | 39°54'36" | 74°34'42" |
| Batsto River | Batsto Lake Dam | Damaged | S | Washington Township | Batsto River | 39°38'37" | 74°39'00" |

decrease of water-surface elevations in relation to bridges or dams at the sites.

The marks were surveyed to determine peak stream elevations by use of various benchmarks and reference marks obtained from the New Jersey Geodetic Survey, Burlington County Engineering Department, FEMA Flood Insurance Studies (2004), and National Geodetic Survey (2004). (Benchmark and reference mark data from New Jersey Geodetic Survey and Burlington County Engineering Department are on file at their respective offices.) For most of the sites, multiple high-water marks were flagged on both the upstream and downstream sides of the dam or bridge. An average peak elevation for the upstream, as well as the downstream, side of the structure at each site was calculated. The final peak stream elevations above the NGVD of 1929 and the NAVD of 1988 are presented in table 3.

Projected elevations of the 10-, 50-, 100-, and 500-year flood recurrence intervals were determined from flood profiles from flood insurance studies and are presented in table 3 (Federal Emergency Management Agency, 1979a, 1979b, 1980, 1983a, 1983b, 1992a, 1992b, 1995, 1996 and U.S. Department of Housing and Urban Development, 1976, 1978a, 1978b, 1979a, 1979b, 1979c). The studies used to determine the projected flood elevations were conducted from 1976 through 1996. Ideally, variables such as alterations or repairs to bridges and dams along the streams, naturally occurring changes in the streambed over time, and most importantly the numerous dam failures that occurred during the July 2004 event are taken into consideration when comparing the flood elevations from this study with projected recurrence-interval flood elevations from the flood insurance studies.

The new and previous peak-of-record elevations above USGS gage datum are listed in table 4. Conditions during the flood in relation to projected flood occurrences are given below.

- South Branch Rancocas Creek flood elevations at six of eight sites exceeded the projected 500-year flood elevations. The elevation at SBR1 in Lumberton approximately equaled the 500-year flood elevation (app. 1-2). A flood profile was not available for SBR0 in Rancocas Heights, which is affected by tide.
- Friendship Creek flood elevations at three sites ranged from greater than the projected 100-year to greater than the 500-year flood elevations. Flood profiles were not available for FRI6 in Camp Inawendiwin, FRI4 near Red Lion, and the upstream side of FRI3 near Red Lion (app. 1-3).
- Haynes Creek flood elevations at three sites ranged from the projected 10- to 500-year flood elevations. The elevation at the site farthest downstream in the reach (HAY1, in Oliphant Mills) exceeded the 500-year elevation (app. 1-4).
- Southwest Branch Rancocas Creek flood elevations at all five sites exceeded the projected 500-year flood elevations (app. 1-5).
- Ballinger Run flood elevations at four sites exceeded the projected 500-year flood elevation. The upstream flood elevation at BAL6 in Medford Lakes exceeded the projected 500-year flood elevation, but the downstream flood elevation exceeded only the projected 10-year flood elevation (app. 1-6). The site is located at Stockwell Dam, which failed. A flood profile is not available for BAL7 at Squaw Lake Dam.
- Barton Run flood elevations at two sites and Barton Run tributary flood elevation at one site ranged from the projected 10-year to greater than the 500-year flood elevations (app. 1-7). A flood profile is not available for the downstream side of BAR5 in Kresson.
- North Branch Rancocas Creek flood elevations at six sites ranged from less than the projected 10-year to approximately the 500-year flood elevation (app. 1-8). Flood profiles are not available for NBR9 in Hanover Furnace and the upstream side of NBR8 in Browns Mills.
- Greenwood Branch flood elevation at one site exceeded the projected 100-year flood elevation (app. 1-9).
- North Branch Pennsauken Creek flood elevation at one site exceeded the projected 50-year flood elevation (app. 1-10).
- South Branch Pennsauken Creek flood elevations at one site exceeded the projected 10-year flood elevation (app. 1-11). The flood elevation recorded at SBP0 near Cherry Hill was equivalent to the projected 50-year flood elevation. A flood profile is not available for the downstream side of SBP0 in Cherry Hill.
- Cooper River flood elevations at two sites exceeded the projected 10-year flood elevation. The flood elevation at the upstream side of COP3 in Kirkwood was less than the projected 10-year flood elevation. The elevation at COP2 in Lawnside exceeded the projected 50-year flood elevation (app. 1-12).
- North Branch Cooper River flood elevations at seven of eight sites ranged from the projected 10- to 100-year flood elevations (app. 1-13). Elevations at sites NBC1 in Erlton and NBC2 in Ellisburg exceeded the projected 10-year flood elevations. The elevation at site NBC5 near Marlton exceeded the projected 50-year flood elevation. All other sites except NBC8 exceeded the projected 100-year elevations. A flood profile is not available for NBC8 in Kresson.

Table 3. Peak stream elevations at 56 sites in Burlington and Camden Counties, south-central New Jersey, during the July 12-13, 2004, flood.

[Federal Emergency Management Agency flood-frequency elevations are from flood profiles in flood insurance studies of the various townships throughout the study area. The location of each site and the location of high-water marks can be found in Appendix 1; *, peak discharge determined, see table 4; ---, no data available; NAVD 88, North American Vertical Datum of 1988; NGVD 29, National Geodetic Vertical Datum of 1929]

| Stream | Study site name / USGS Station number | Location (road or dam) | Approximate distance upstream from mouth (miles) | July 12-13, 2004 elevation, in feet above NAVD 88 | July 12-13, 2004 elevation, in feet above NGVD 29 | Federal Emergency Management Agency water-surface elevations, in feet above NGVD 29 | | | |
|-----------------------------|---------------------------------------|--|--|---|---|---|---------------|----------------|----------------|
| | | | | | | 10-year flood | 50-year flood | 100-year flood | 500-year flood |
| South Branch Rancocas Creek | SBR7 / 01465835 | Ridge Road | 16.5 | 34.6 | 35.9 | 31.6 | 32.1 | 32.3 | 33.2 |
| | SBR6 / --- | Hillards Bridge Road | 14.3 | 34.7 | 35.9 | 31.5 | 32.0 | 32.2 | 33.1 |
| | SBR4b / --- | Vincentown Mill Dam | 13.5 | 29.6 | 30.8 | 26.0 | 26.6 | 26.8 | 27.3 |
| | SBR4a / --- | Mill Street / Church Road (County Route 616) | 13.4 | 28.7 | 30.0 | 26.0 | 26.5 | 26.7 | 27.2 |
| | SBR3* / 01465850 | Landing Street (County Route 641) | 12.1 | 28.9 | 30.1 | 24.2 | 24.7 | 25.1 | 26.0 |
| | SBR2 / 01465854 | Eayrestown-Newbolds Road | 9.1 | --- | --- | --- | --- | --- | --- |
| | SBR1 / --- | Lumberton / Main Street (County Route 541) | 6.0 | 28.2 | 29.5 | 22.9 | 23.5 | 23.8 | 24.5 |
| | SBR0 / 01465917 | Mame Highway (County Route 537) | 3.2 | 27.9 | 29.1 | 22.4 | 23.0 | 23.3 | 23.7 |
| | FR16 / --- | Camp Inawendiwin Middle Dam | 6.2 | 24.4 | 25.6 | 19.0 | 19.4 | 19.6 | 20.0 |
| | FR15 / 01465807 | Powell Place Road | 5.5 | 23.9 | 25.1 | 18.9 | 19.3 | 19.5 | 19.9 |
| | FR14 / --- | Private earthen dam with concrete spillway | 4.5 | 18.0 | 19.2 | 12.5 | 13.1 | 13.4 | 15.4 |
| | FR13 / 01465825 | State Route 70 | 3.6 | 17.6 | 18.8 | 12.4 | 13.0 | 13.3 | 15.4 |
| Friendship Creek | FR12 / --- | Old forge Lake Dam | 3.0 | 14.2 | 15.4 | 8.7 | 9.8 | 10.6 | 15.3 |
| | FR11 / 01465833 | Retreat Road | 0.6 | 14.0 | 15.2 | 8.7 | 9.8 | 10.6 | 15.3 |
| | FR10 / --- | Private earthen dam with concrete spillway | 4.5 | 10.1 | 11.2 | --- | --- | --- | --- |
| | FR9 / --- | State Route 70 | 3.6 | 9.6 | 10.7 | --- | --- | --- | --- |
| | FR8 / --- | State Route 70 | 3.6 | 70.1 | 71.3 | --- | --- | --- | --- |
| Friendship Creek | FR7 / --- | State Route 70 | 3.6 | 65.6 | 66.8 | --- | --- | --- | --- |
| | FR6 / --- | State Route 70 | 3.6 | 61.4 | 62.6 | 58.2 | 59.1 | 59.5 | 60.4 |
| | FR5 / --- | State Route 70 | 3.6 | 61.2 | 62.4 | 57.6 | 58.2 | 58.5 | 59.1 |
| | FR4 / --- | State Route 70 | 3.6 | 54.0 | 55.2 | --- | --- | --- | --- |
| | FR3 / --- | State Route 70 | 3.6 | 51.9 | 53.1 | --- | --- | --- | --- |
| Friendship Creek | FR2 / --- | State Route 70 | 3.6 | 47.0 | 48.2 | --- | --- | --- | --- |
| | FR1 / --- | State Route 70 | 3.6 | 45.6 | 46.8 | 45.6 | 46.0 | 46.3 | 47.1 |
| | FR0 / --- | State Route 70 | 3.6 | 45.5 | 46.8 | 45.6 | 45.8 | 46.2 | 46.8 |
| | FR-1 / --- | State Route 70 | 3.6 | 44.9 | 46.2 | 45.1 | 45.6 | 45.8 | 46.5 |
| | FR-2 / --- | State Route 70 | 3.6 | 35.3 | 36.5 | 32.6 | 33.3 | 33.6 | 35.2 |
| Friendship Creek | FR-3 / --- | State Route 70 | 3.6 | 34.5 | 35.8 | 32.3 | 32.8 | 32.9 | 33.5 |
| | FR-4 / --- | State Route 70 | 3.6 | 34.5 | 35.8 | 32.3 | 32.8 | 32.9 | 33.5 |
| | FR-5 / --- | State Route 70 | 3.6 | 34.5 | 35.8 | 32.3 | 32.8 | 32.9 | 33.5 |
| | FR-6 / --- | State Route 70 | 3.6 | 34.5 | 35.8 | 32.3 | 32.8 | 32.9 | 33.5 |
| | FR-7 / --- | State Route 70 | 3.6 | 34.5 | 35.8 | 32.3 | 32.8 | 32.9 | 33.5 |

Table 3. Peak stream elevations at 56 sites in Burlington and Camden Counties, south-central New Jersey, during the July 12-13, 2004, flood.—Continued

[Federal Emergency Management Agency flood-frequency elevations are from flood profiles in flood insurance studies of the various townships throughout the study area. The location of each site and the location of high-water marks can be found in Appendix 1; *, peak discharge determined, see table 4; ---, no data available; NAVD 88, North American Vertical Datum of 1988; NGVD 29, National Geodetic Vertical Datum of 1929]

| Stream | Study site name / USGS Station number | Location (road or dam) | Approximate distance upstream from mouth (miles) | July 12-13, 2004 elevation, in feet above NAVD 88 | July 12-13, 2004 elevation, in feet above NGVD 29 | Federal Emergency Management Agency water-surface elevations, in feet above NGVD 29 | | | |
|---------------------------------|---------------------------------------|--|--|---|---|---|---------------|----------------|----------------|
| | | | | | | 10-year flood | 50-year flood | 100-year flood | 500-year flood |
| Haynes Creek | HAY4 / 0146587105 | Kettle Run (Haynes Creek tributary) at Centennial Dam Road | 4.8 | 62.2 | 63.3 | 63.3 | 64.2 | 64.8 | 66.1 |
| | | | | 52.9 | 54.1 | 53.8 | 54.1 | 54.5 | 56.7 |
| | HAY3 / 01465872 | Breakneck Road (Taunton Lake outlet) | 3.8 | 52.1 | 53.3 | 53.3 | 54.0 | 54.4 | 56.4 |
| | | | | 48.3 | 49.5 | 48.3 | 49.2 | 49.6 | 50.4 |
| | HAY2 / 01465873 | Falls Road (Lake Pine outlet) | 2.7 | 44.8 | 46.0 | 46.0 | 46.8 | 47.1 | 49.3 |
| Southwest Branch Rancocas Creek | HAY1 / 01465878 | Upstream of Pine Lake Dam / downstream of Himmelein Road | 0.5 | 42.9 | 44.1 | 41.2 | 42.2 | 42.8 | 44.5 |
| | | | | 40.1 | 41.3 | 36.8 | 37.4 | 37.7 | 38.4 |
| | SWB5 / 01465870 | Hartford Road | 8.3 | 38.6 | 39.8 | 32.6 | 34.2 | 35.3 | 38.0 |
| | | | | 38.4 | 39.6 | 32.7 | 34.8 | 35.8 | 38.6 |
| Ballinger Run | SWB4* / 01465880 | South Main Street | 7.2 | 38.0 | 39.2 | 32.6 | 34.8 | 35.7 | 38.5 |
| | | | | 36.9 | 38.1 | 29.8 | 31.9 | 32.9 | 35.8 |
| | SWB3 / 01465882 | State Route 70 / Main Street | 5.8 | 35.9 | 37.1 | 29.7 | 31.7 | 32.7 | 35.2 |
| | | | | 33.1 | 34.4 | 27.3 | 28.7 | 29.3 | 31.3 |
| | SWB2 / 01465888 | Church Road (Kirbys Mill) | 4.5 | 32.8 | 33.9 | 27.3 | 28.6 | 29.3 | 31.2 |
| | | | | 29.4 | 30.6 | 26.6 | 27.0 | 27.3 | 28.0 |
| | SWB1 / 01465900 | Fostertown-Eayrestown Road (Bridge Road) | 0.2 | 28.9 | 30.1 | 24.6 | 26.9 | 27.2 | 27.7 |
| | | | | 18.8 | 20.0 | 12.3 | 13.0 | 13.4 | 15.3 |
| Ballinger Run | BAL7 / --- | Squaw Lake Dam | 4.3 | 17.7 | 18.9 | 12.2 | 12.8 | 13.0 | 15.3 |
| | | | | 79.6 | 80.8 | --- | --- | --- | --- |
| | BAL6 / --- | Upstream of Lake Stockwell Dam / downstream of private road | 3.4 | 77.1 | 78.3 | --- | --- | --- | --- |
| | | | | 73.7 | 75.0 | 73.3 | 74.0 | 74.2 | 74.5 |
| | BAL5 / --- | Upstream of Upper Aetna Lake Dam / downstream of Beach Drive | 2.7 | 68.8 | 70.0 | 69.4 | 71.2 | 71.4 | 71.7 |
| | | | | 68.0 | 69.2 | 65.7 | 66.3 | 66.7 | 67.0 |
| | BAL4 / --- | Stokes Road (County Route 541) | 1.7 | 63.8 | 65.0 | 62.3 | 62.5 | 62.8 | 63.0 |
| | | | | 58.5 | 59.7 | 50.0 | 50.7 | 51.3 | 52.2 |
| | BAL3 / 01465876 | Upstream of Birchwood Lake Dam / downstream of Jackson Road | 0.9 | 58.3 | 59.5 | 49.8 | 50.4 | 50.8 | 51.7 |
| | | | | 49.7 | 50.9 | 46.8 | 47.5 | 47.9 | 48.7 |
| Ballinger Run | BAL2 / 01465877 | Upstream of Timber Lake Dam / downstream of Ramblewood Lane | 0.3 | 47.4 | 48.6 | 46.4 | 46.7 | 46.9 | 47.2 |
| | | | | 47.4 | 48.6 | 46.4 | 46.7 | 46.9 | 47.2 |
| | | | | 42.0 | 43.2 | 36.7 | 38.0 | 38.4 | 39.1 |

Table 3. Peak stream elevations at 56 sites in Burlington and Camden Counties, south-central New Jersey, during the July 12-13, 2004, flood.—Continued

[Federal Emergency Management Agency flood-frequency elevations are from flood profiles in flood insurance studies of the various townships throughout the study area. The location of each site and the location of high-water marks can be found in Appendix 1; *, peak discharge determined, see table 4; ---, no data available; NAVD 88, North American Vertical Datum of 1988; NGVD 29, National Geodetic Vertical Datum of 1929]

| Stream | Study site name / USGS Station number | Location (road or dam) | Approximate distance upstream from mouth (miles) | July 12-13, 2004 elevation, in feet above NAVD 88 | July 12-13, 2004 elevation, in feet above NGVD 29 | Federal Emergency Management Agency water-surface elevations, in feet above NGVD 29 | | | |
|-------------------------------|---------------------------------------|--|--|---|---|---|---------------|----------------|----------------|
| | | | | | | 10-year flood | 50-year flood | 100-year flood | 500-year flood |
| Barton Run | BAR5 / 01465860 | Upstream of Union Mill Lake Dam | 6.0 | 86.2 | 87.4 | 87.0 | 87.7 | 88.1 | 89.3 |
| | | Downstream of State Route 73 | | 83.8 | 85.0 | --- | --- | --- | --- |
| | BAR4 / --- | Taunton Lake Road (County Route 544) | 4.1 | 57.4 | 58.6 | 54.7 | 57.0 | 57.3 | 57.7 |
| | | | | 56.8 | 58.0 | 54.5 | 55.6 | 56.0 | 56.9 |
| | BAR2 / 01465865 | Tuckerton Road (County Route 620) | 1.3 | 43.6 | 44.8 | 42.4 | 43.7 | 44.3 | 45.6 |
| | | | | 42.8 | 44.0 | 42.4 | 43.6 | 44.1 | 45.5 |
| | BAR3 / --- | Braddock Mill Road | 0.9 | 75.8 | 77.0 | 72.8 | 73.2 | 75.5 | 76.4 |
| | | | | 68.3 | 69.4 | 68.8 | 69.3 | 69.7 | 70.3 |
| North Branch Rancocas Creek | NBR9 / 01465950 | Hanover Lake Outlet (Military Road) | 29.7 | --- | --- | --- | --- | --- | --- |
| | | | | 68.5 | 69.7 | --- | --- | --- | --- |
| | NBR8 / 01465970 | Upstream of Browns Mills Dam / Downstream of Lakehurst Road (County Route 530) | 26.0 | 59.5 | 60.8 | --- | --- | --- | --- |
| | | | | 54.2 | 55.4 | 51.5 | 52.3 | 52.8 | 54.3 |
| | NBR7 / 01465980 | Springfield/New Lisbon Road (County Route 646) | 22.7 | 43.1 | 44.4 | 46.7 | 47.3 | 47.7 | 48.4 |
| | | | | 41.8 | 43.1 | 41.6 | 42.8 | 44.3 | 44.6 |
| | NBR5* / 01467000 | Upstream of Hanover Street (County Route 616) / Downstream of dam | 18.2 | 34.4 | 35.6 | 33.8 | 35.2 | 35.7 | 37.0 |
| | | | | 33.5 | 34.7 | 33.4 | 34.7 | 35.3 | 36.4 |
| | NBR4 / 01467002 | Birmingham Road | 15.0 | 28.4 | 29.7 | 28.5 | 30.5 | 31.3 | 32.6 |
| | | | | 28.0 | 29.2 | 28.5 | 30.3 | 31.2 | 32.5 |
| | NBR3 / 01467003 | US Route 206 | 12.0 | 23.6 | 24.8 | 24.0 | 25.9 | 26.7 | 28.8 |
| | | | | 22.9 | 24.1 | 23.7 | 25.5 | 26.2 | 27.5 |
| Greenwood Branch | NBR1b / --- | Iron Works Dam | 6.7 | 12.3 | 13.5 | 14.4 | 15.1 | 15.3 | 16.3 |
| | | | | 11.3 | 12.5 | 10.0 | 11.8 | 12.7 | 15.4 |
| | NBR1a / 01467006 | Pine Street | 6.6 | 10.5 | 11.7 | 9.9 | 11.6 | 12.6 | 15.4 |
| | | | | 10.5 | 11.7 | 9.9 | 11.6 | 12.6 | 15.4 |
| North Branch Pennsauken Creek | GRE1* / 01466900 | Fourmile Road (County Route 646) | 0.7 | 43.1 | 44.4 | 42.0 | 43.5 | 44.0 | 45.5 |
| | | | | 43.0 | 44.3 | 41.7 | 42.8 | 43.4 | 44.7 |
| | NBP1 / 01467069 | Kings Highway (Strawbridge Lake outlet) | 3.9 | 12.8 | 13.9 | 10.3 | 12.4 | 13.5 | 17.7 |
| | | | | 12.3 | 13.4 | 10.1 | 11.9 | 13.1 | 16.9 |

Table 3. Peak stream elevations at 56 sites in Burlington and Camden Counties, south-central New Jersey, during the July 12-13, 2004, flood.—Continued

[Federal Emergency Management Agency flood-frequency elevations are from flood profiles in flood insurance studies of the various townships throughout the study area. The location of each site and the location of high-water marks can be found in Appendix 1; *, no data available; NAVD 88, North American Vertical Datum of 1988; NGVD 29, National Geodetic Vertical Datum of 1929]

| Stream | Study site name / USGS Station number | Location (road or dam) | Approximate distance upstream from mouth (miles) | July 12-13, 2004 elevation, in feet above NAVD 88 | July 12-13, 2004 elevation, in feet above NGVD 29 | Federal Emergency Management Agency water-surface elevations, in feet above NGVD 29 | | | |
|-------------------------------|---------------------------------------|------------------------------------|--|---|---|---|---------------|----------------|----------------|
| | | | | | | 10-year flood | 50-year flood | 100-year flood | 500-year flood |
| South Branch Pennsauken Creek | SBP1 / 01467080 | Old Kings Highway (State Route 41) | 5.9 | 26.4 | 27.5 | 23.6 | 28.4 | 30.2 | 36.0 |
| | | | | 26.2 | 27.4 | 23.2 | 28.4 | 29.7 | 35.7 |
| | SBP0* / 01467081 | Mill Road | 4.6 | 18.8 | 19.9 | 19.0 | 19.9 | 20.4 | 21.7 |
| | | | | --- | --- | --- | --- | --- | --- |
| Cooper River | COP3* / 01467130 | Kirkwood Lake Dam | 14.8 | 59.3 | 60.4 | 60.6 | 62.8 | 64.0 | 67.4 |
| | | | | 57.3 | 58.4 | 56.9 | 62.1 | 63.6 | 67.3 |
| | COP2 / 01467140 | Woodcrest Avenue | 11.3 | 35.8 | 37.0 | 31.8 | 36.1 | 39.2 | 49.9 |
| | | | | 35.0 | 36.2 | 31.4 | 35.4 | 38.5 | 49.6 |
| | COP1* / 01467150 | Kings Highway (State Route 41) | 8.3 | 14.0 | 15.2 | 13.5 | 16.0 | 28.5 | 29.0 |
| | | | | 13.5 | 14.6 | 13.0 | 16.0 | 17.7 | 23.8 |
| | NBC8 / 01467155 | Kresson Road | 8.7 | 81.1 | 82.2 | --- | --- | --- | --- |
| | | | | 80.0 | 81.1 | 79.6 | 80.3 | 80.8 | 83.8 |
| North Branch Cooper River | NBC7 / --- | Evesham Road | 7.6 | 70.9 | 72.0 | 68.6 | 70.4 | 71.3 | 76.2 |
| | | | | 69.2 | 70.4 | 67.7 | 69.5 | 70.0 | 71.7 |
| | NBC6 / --- | Cropwell Road | 5.8 | 53.6 | 54.8 | 51.6 | 53.0 | 53.8 | 55.7 |
| | | | | 52.8 | 54.0 | 51.3 | 52.4 | 53.1 | 55.1 |
| | NBC5* / 01467160 | Springdale Road | 4.4 | 43.0 | 44.2 | 40.7 | 42.6 | 46.1 | 49.3 |
| | | | | 42.6 | 43.8 | 40.2 | 42.4 | 46.0 | 49.2 |
| | NBC4 / --- | Markress Road (Cuthbert Road) | 3.2 | 35.4 | 36.6 | 29.1 | 31.9 | 33.9 | 44.2 |
| | | | | 34.0 | 35.2 | 28.6 | 31.2 | 33.6 | 44.1 |
| | NBC3 / | Covered Bridge Road | 2.4 | 26.9 | 28.0 | 21.2 | 23.0 | 24.9 | 31.5 |
| | | | | 24.4 | 25.5 | 20.6 | 21.4 | 23.6 | 27.7 |
| | NBC2 / 01467180 | Brace Road | 1.0 | 17.0 | 18.2 | 16.1 | 19.6 | 22.8 | 26.3 |
| | | | | 16.3 | 17.4 | 15.7 | 18.7 | 21.7 | 25.8 |
| | NBC1 / 01467181 | Park Boulevard | 0.1 | 12.9 | 14.0 | 12.8 | 15.6 | 17.2 | 23.1 |
| | | | | 12.2 | 13.4 | 12.7 | 15.4 | 17.1 | 22.8 |

Table 4. Historical peak streamflow and peak stream elevations and those recorded during the July 12-13, 2004, flood at U.S. Geological Survey (USGS) continuous-record stream gages and crest-stage gages in Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey.

| Study site name / USGS station number | Site name | Drainage area (mi ²) | Remarks | Date | Peak streamflow (ft ³ /s) | Peak streamflow per square mile (ft ³ /s/mi ²) | Peak stream elevation (in feet above gage datum) | Time | Recurrence interval (years) | Period of record (water years ¹) |
|--|---|--|-------------------------|-----------|--|--|---|------|-----------------------------------|---|
| | | | | | | | | | | |
| SBP3 / 01465850 | South Branch South Branch Rancocas Creek at Vincentown, NJ | 64.5 | Previous peak of record | 8/28/1978 | 1,320 | 20.5 | 7.98 | --- | 10 | 1961-75, 1999-2002, 2003-2004 |
| SWB4 / 01465880 | Southwest Branch Rancocas Creek at Medford, NJ | 47.20 | Previous peak of record | 7/13/2004 | 4,160 | 64.5 | 12.34 | 0815 | >100 | 1983-95, 2004 |
| SWB3 / 01465882 | Southwest Branch Rancocas Creek at Route 70 at Medford, NJ | 47.90 | Previous peak of record | 7/05/1989 | 3,300 | 69.9 | 15.3 | --- | 60 | 1978-82, 2004 |
| --- | McDonalds Branch in Byrne State Forest, NJ (formerly Lebanon State Forest) | 2.35 | Previous peak of record | 7/13/2004 | 2,830 | 59.1 | 7.33 | --- | --- | 1953-2004 |
| GRE1 / 01466900 | Greenwood Branch at New Lisbon, NJ | 77.9 | Tied peak of record | 7/13/2004 | 38 | 16.2 | 2.33 | 0015 | 50 | 1998-2004 |
| NBR5 / 01467000 | North Branch Rancocas Creek at Pember- ton, NJ | 118 | Previous peak of record | 5/11/1998 | 810 | 10.4 | 7.78 | --- | --- | 1921-2004 |
| NBP1 / 01467069 | North Branch Pennsauken Creek near Moorestown, NJ | 12.8 | Previous peak of record | 7/13/2004 | 1,080 | 13.9 | 8.91 | 2330 | 30 | 1975-88, 2004 |
| SBP1 / 01467080 | South Branch Pennsauken Creek at Maple Shade, NJ | 8.10 | Previous peak of record | 8/21/1939 | 1,730 | 14.7 | 10.77 | --- | 20 | 1964-68, 2004 |
| SBP0 / 01467081 | South Branch Pennsauken Creek at Cherry Hill, NJ | 8.98 | Previous peak of record | 7/14/2004 | 730 | 90.1 | 6.09 | --- | --- | 1967-76, 1978-2004 |
| COP3 / 01467130 | Cooper River at Kirkwood, NJ | 5.10 | Previous peak of record | 7/13/2004 | 1,560 | 174 | 11.76 | 0400 | 75 | 1964-1980, 2004 |
| COP1 / 01467150 | Cooper River at Haddonfield, NJ | 17.0 | Previous peak of record | 8/10/1967 | 390 | 76.4 | 2.47 | --- | 20 | 1963-2004 |
| NBC5 / 01467160 | North Branch Cooper River near Marlton, NJ | 5.34 | Previous peak of record | 7/12/2004 | 450 | 88.2 | 2.63 | --- | 30 | 1964-1988, 2004 |
| NBC2 / 01467180 | North Branch Cooper River at Ellipsisburg, NJ | 10.5 | Previous peak of record | 7/12/2004 | 2,940 | 173 | 5.46 | --- | 90 | 1964-75, 2004 |

¹ Water year is the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ending September 30, 2002, is called the "2002 water year."

² Recorded at site and gage datum then in use. Previous stream gage was located 900 feet downstream from current location, below a dam, at datum 6.54 feet lower.

Peak flows

Peak flows were determined at nine sites within the study area: five sites in the Rancocas Creek Basin, three sites in the Cooper River Basin, and one site in the Pennsauken Creek Basin. New peak-of-record flows were established at eight sites. Sufficient historical data were available to determine flood frequency of peak discharge at eight sites, four of which exceeded the 100-year recurrence interval. Six of the nine sites are at continuous stream gages. The new and previous peak-of-record flows at each site are listed in table 4. The hydrographs of streamflow at the continuous stream gages are shown in figure 5 (Centinaro and others, 2005). Sites in and around the study area with their respective flood-recurrence intervals as determined by peak streamflow on July 12-13, 2004, are shown in figure 6.

Of the five streamflows within the Rancocas Creek Basin, four were determined at continuous-record stream gages. The gages are located on the North and South Branches Rancocas Creek, McDonalds Branch, and Greenwood Branch. The fifth streamflow was calculated by indirect measurement for the Southwest Branch Rancocas Creek at Medford, a discontinued USGS crest-stage gage. The station numbers, site identifiers, and locations are as follows:

- SBR3/01465850 South Branch Rancocas Creek at Vincentown (gage),
- SWB4/01465880 Southwest Branch Rancocas Creek at Medford (indirect),
- GRE1/01466900 Greenwood Branch at New Lisbon (gage),
- 01466500 McDonalds Branch in Byrne State Forest (gage), and
- NBR5/01467000 North Branch Rancocas Creek at Pemberton (gage).

Peak-of-record flows of 4,160 ft³/s and 12,400 ft³/s, determined for the South and Southwest Branches Rancocas Creek, respectively, were approximately 1.8 and 3.2 times the 100-year recurrence intervals, respectively. Three dams failed and five were damaged upstream from the South Branch Rancocas Creek at Vincentown stream gage. The greatest rainfall and most of the dam failures occurred in the upper reaches of the Southwest Branch Rancocas Creek, which enters the South Branch Rancocas Creek 4.5 miles downstream from Vincentown. Twelve dams failed and 17 dams were damaged upstream from the Southwest Branch Creek in Medford (SWB4). The maximum streamflow per square mile of 263 ft³/s/mi² determined for the Southwest Branch Rancocas Creek in Medford was the greatest of all flows per square mile in the study area (table 4).

The peak-of-record flow of 1,840 ft³/s on the North Branch Rancocas Creek at Pemberton coincides with a recurrence interval of approximately 35 years. Pemberton is 4.6 miles downstream from the Greenwood Branch site where a

flow of 1,080 ft³/s was calculated. The streamflow records for Greenwood Branch, a tributary to the North Branch Rancocas Creek, are not sufficient to determine the flood-recurrence interval. The maximum streamflow per square mile increased from 13.9 ft³/s/mi² at the Greenwood Branch site to 15.6 ft³/s/mi² at the North Branch Rancocas Creek site. The McDonalds Branch peak flow of 38 ft³/s, which has a recurrence interval of approximately 50 years, equaled the previous peak-of-record flow determined at the site in 1958.

Of the three discharges within the Cooper River Basin, two were determined on the Cooper River: one at a continuous stream gage and the other by indirect method at a discontinued crest-stage gage. The third discharge was determined at a discontinued crest-stage gage on the North Branch Cooper River. The station numbers, site identifiers, and locations for sites in the Cooper River Basin are as follows:

- COP3/01467130 Cooper River at Kirkwood (indirect),
- COP1/01467150 Cooper River at Haddonfield (gage), and
- NBC5/01467160 North Branch Cooper River near Marlton (gage).

The Cooper River peak-of-record flow of 450 ft³/s at Kirkwood had a recurrence interval of approximately 30 years. The peak flow 6.5 miles downstream at Haddonfield was 3,300 ft³/s, which was approximately 1.1 times the 100-year recurrence interval. The maximum streamflow per square mile increased from 88.2 ft³/s/mi² at the Kirkwood site to 194 ft³/s/mi² at the Haddonfield site.

The North Branch Cooper River peak-of-record flow of 1,200 ft³/s near Marlton was approximately 1.5 times the 100-year recurrence interval. The North Branch Cooper River enters the Cooper River 0.7 miles downstream from the Haddonfield site.

Within the Pennsauken Creek Basin, a new peak-of-record flow was determined on the South Branch Pennsauken Creek at a continuous stream gage in Cherry Hill. The peak flow of 1,560 ft³/s has a recurrence interval of approximately 75 years.

Flood extent

The heavy rainfall and consequent flooding was limited to the three basins within the study area. Peak flows determined at USGS stream gages surrounding the area, in general, had less than 2-year recurrence intervals (table 5). A map showing sites in and around the study area with their respective flood-recurrence intervals is presented in figure 6. Streamflows at several of the continuous stream gages outside of the study area actually had higher peaks days later because of isolated showers that occurred on July 14-15. Hydrographs of streamflow at continuous stream gages outside the study area are shown in figure 7 (Centinaro and others, 2005).

Only three sites outside the study area experienced streamflows with greater than 2-year recurrence intervals as a

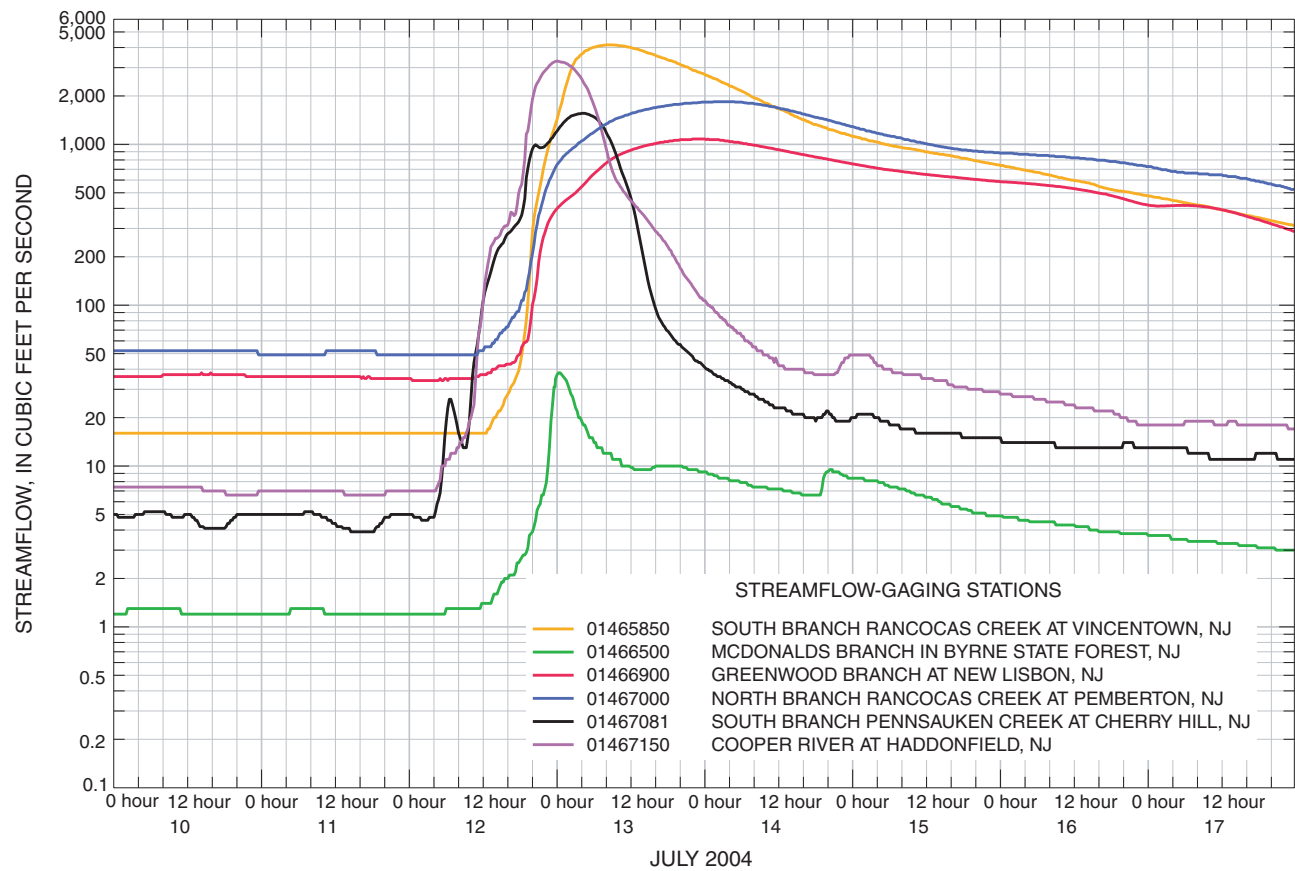


Figure 5. Hydrographs showing streamflow at six continuous-record stream gages within the Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey, July 10-17, 2004.

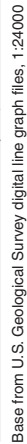


Figure 6. Stream gages and flood frequencies of peak discharge from July 12-13, 2004, south-central New Jersey.

Table 5. Historical flood peaks and peaks during the July 12-13, 2004, flood at U.S. Geological Survey (USGS) stream gages outside the Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey.

[mi², square miles; ft³/s, cubic feet per second; ft³/s/mi², cubic feet per second per square mile; <, less than; >, greater than; ---, no data available; *, indicates gage was recording during at least one of the floods of 1938, 1939, and 1940.]

| USGS station number | Site name | Drainage area (mi ²) | Remarks | Date | Peak streamflow (ft ³ /s) | Peak streamflow per square mile (ft ³ /s/mi ²) | Peak stream elevation (in feet above gage datum) | Time | Recurrence interval (years) | Period of record (water years ¹) |
|---------------------|--|----------------------------------|-----------------------|------------|--------------------------------------|---|--|------|-----------------------------|--|
| 01408500 | Toms River near Toms River, NJ | 123 | July 12-13 rain event | 7/13/2004 | 708 | 5.76 | 7.60 | 1745 | <2 | *1928-2004 |
| | | | Peak of record | 9/23/1938 | 2,000 | 16.3 | 12.50 | --- | 50 | |
| 01408582 | Michaels Branch tributary at Keswick Grove, NJ | 0.67 | July 12-13 rain event | 7/13/2004 | --- | --- | 3.34 | --- | --- | 1999-2004 |
| | | | Peak of record | 9/16/1999 | --- | --- | 3.65 | --- | --- | |
| 01409088 | Brookville Creek at Brookville, NJ | 0.50 | July 12-13 rain event | 7/14/2004 | 4.7 | 9.4 | 4.34 | --- | --- | 1999-2004 |
| | | | Peak of record | 9/16/1999 | 10 | 50.0 | 4.92 | --- | --- | |
| 01409400 | Mullica River near Batsto, NJ | 46.7 | July 12-13 rain event | 7/12/2004 | 60 | 1.28 | 0.87 | 2345 | <2 | 1957-2004 |
| | | | Peak of record | 2/26/1976 | 1,840 | 39.4 | 6.14 | --- | 70 | |
| 01409500 | Batsto River at Batsto, NJ | 67.8 | July 12-13 rain event | 7/14/2004 | 1,020 | 15.0 | 7.11 | 0715 | 10 | *1927-2004 |
| | | | Peak of record | 8/20/1939 | --- | --- | 28.70 | --- | --- | |
| 01410000 | Oswego River at Harrisville, NJ | 72.4 | July 12-13 rain event | 7/13/2004 | 53 | 0.73 | 2.91 | 0000 | <2 | *1930-2004 |
| | | | Peak of record | 8/20/1939 | 1,390 | 19.2 | 9.54 | --- | 100 | |
| 01410150 | East Branch Bass River near New Gretna, NJ | 8.11 | July 12-13 rain event | 7/13/2004 | 12 | 1.48 | 3.95 | 0700 | --- | 1978-2004 |
| | | | Peak of record | 8/21/1997 | 1,130 | 139 | 7.28 | --- | >100 | |
| 01411000 | Great Egg Harbor River at Folsom, NJ | 57.1 | July 12-13 rain event | 7/16/2004 | 96 | 1.68 | 3.97 | 0300 | <2 | *1925-2004 |
| | | | Peak of record | 9/03/1940 | 1,440 | 25.2 | 9.09 | --- | >100 | |
| 01411456 | Little Ease Run near Clayton, NJ | 9.77 | July 12-13 rain event | 7/13/2004 | 9.3 | 0.95 | 2.18 | 0715 | --- | 1988-2004 |
| | | | Peak of record | 12/11/2003 | 155 | 15.9 | 4.5 | 1745 | --- | |
| 01464500 | Crosswicks Creek at Extonville, NJ | 81.5 | July 12-13 rain event | 7/13/2004 | 1,280 | 15.7 | 9.25 | 1930 | <2 | *1940-51, 1953-2004 |
| | | | Peak of record | 9/01/1978 | 4,860 | 59.6 | 14.18 | --- | 40 | |
| 01464533 | Crafts Creek at Route 68 at George-town, NJ | 0.58 | July 12-13 rain event | 7/13/2004 | 13 | 22.4 | 2.66 | --- | --- | 1955-2004 |
| | | | Peak of record | 9/16/1999 | 43 | 74.1 | 4.57 | --- | --- | |

Table 5. Historical flood peaks and peaks during the July 12-13, 2004, flood at U.S. Geological Survey (USGS) stream gages outside the Rancocas Creek, Cooper River, and Pennsauken Creek Basins, south-central New Jersey.—Continued

[mi², square miles; ft³/s, cubic feet per second; ft³/mi², cubic feet per second per square mile; <, less than; >, greater than; ---, no data available; *, indicates gage was recording during at least one of the floods of 1938, 1939, and 1940.]

| USGS station number | Site name | Drainage area (mi ²) | Remarks | Date | Peak streamflow (ft ³ /s) | Peak streamflow per square mile (ft ³ /s/mi ²) | Peak stream elevation (in feet above gage datum) | Time | Recurrence interval (years) | Period of record (water years ¹) |
|---------------------|--|----------------------------------|-----------------------|------------|--------------------------------------|---|--|------|-----------------------------|--|
| 01464538 | Crafts Creek at Columbus, NJ | 5.38 | July 12-13 rain event | 7/13/2004 | 58 | 10.8 | 3.47 | --- | <2 | 1978-2004 |
| | | | Peak of record | 7/06/1989 | 880 | 164 | 10.25 | --- | 25 | |
| 01467305 | Newton Creek at Collingswood, NJ | 1.33 | July 12-13 rain event | 7/12/2004 | 264 | 198 | 4.99 | --- | 15 | 1964-2004 |
| | | | Peak of record | 7/14/1994 | 328 | 247 | 6.82 | --- | 85 | |
| 01467317 | South Branch Newton Creek at Had-don Heights, NJ | 0.63 | July 12-13 rain event | 7/12/2004 | 232 | 368 | 4.62 | --- | 10 | 1964-2004 |
| | | | Peak of record | 9/01/1978 | 295 | 468 | 4.62 | --- | 20 | |
| 01467357 | Gravelly Run at Somerdale, NJ | 0.35 | July 12-13 rain event | 7/12/2004 | 37 | 106 | 1.90 | --- | --- | 1997-2004 |
| | | | Peak of record | 12/11/2003 | 176 | 503 | 4.65 | --- | --- | |
| 01475000 | Mantua Creek at Pitman, NJ | 6.05 | July 12-13 rain event | 7/12/2004 | 76 | 12.6 | ³ 3.14 | 2100 | <2 | *1940-76, 2003-2004 |
| | | | Peak of record | 9/01/1940 | ⁴ 4,200 | 694 | ⁵ 6.64 | --- | >100 | |
| 01477120 | Raccoon Creek near Swedesboro, NJ | 26.9 | July 12-13 rain event | 7/12/2004 | 84 | 3.12 | 8.82 | 2115 | <2 | 1966-2004 |
| | | | Peak of record | 8/10/1967 | 3,530 | 131 | 17.44 | --- | 100 | |

¹ Water year is the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ending September 30, 2002, is called the "2002 water year."

² Obtained from floodmark.

³ Stream elevation below Wadsworth Dam.

⁴ By computation of peak flow over dam and earthen dike. Peak occurred before earthen dike broke.

⁵ Stream elevation above Wadsworth Dam.

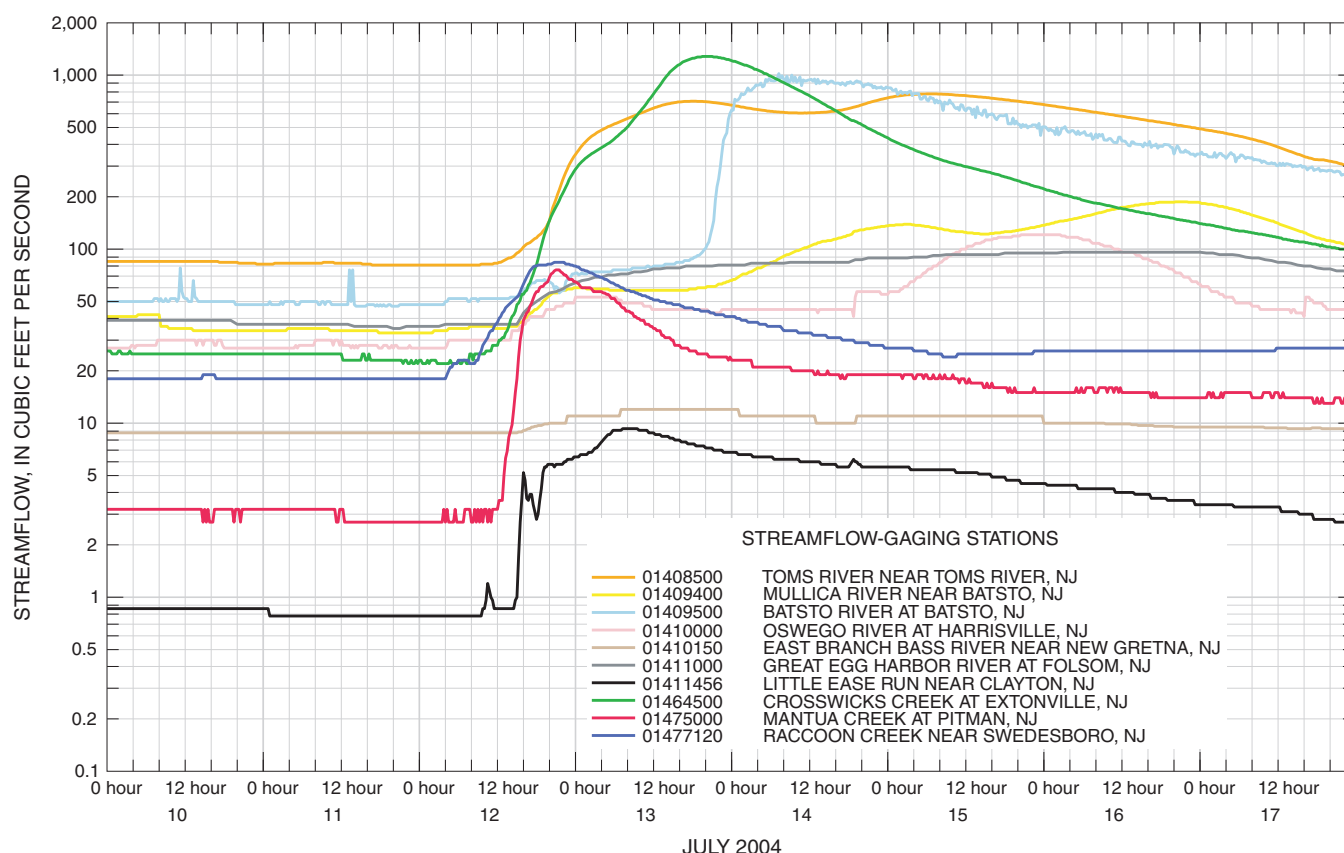


Figure 7. Hydrographs showing streamflow at 10 continuous-record stream gages surrounding the Rancocas Creek, Cooper River, and Pennauken Creek Basins, south-central New Jersey, July 10-17, 2004.

result of the July 12-13 storm. Peaks discharges determined at Newton Creek at Collingswood (01467305) and South Branch Newton Creek at Haddon Heights (01467317) in the Newton Creek Basin, which is immediately south of the Cooper River Basin, were equivalent to 10- and 15-year recurrence intervals, respectively (fig. 2 and 6). A rainfall total of 4.17 inches was recorded in the area. Peak flow determined at the Batsto River at Batsto (01409500), located south of the study area, was equivalent to a 10-year recurrence interval. The dam at this site was reported as damaged.

Ancillary hydrologic components

The July 12-13, 2004, flood was primarily caused by the unusually heavy rainfall, coupled with multiple dam failures. Tidal and ground-water conditions did not exacerbate the high-water conditions; however, these aspects are documented to provide a comprehensive hydrologic assessment of the flood.

Effects of tides

The timing of the flood peaks at USGS stream gages South Branch Rancocas Creek at Vincentown (SBR3; app.

1-2) and North Branch Rancocas Creek at Pemberton (NRB5; app. 1-8) were compared to the timing of the tide cycles recorded at USGS stream gage Delaware River at Burlington (fig. 2) and the NOAA-predicted tide cycles of South Branch Rancocas Creek at Hainesport (SBR0; app. 1-2). The stream gage on the South Branch Rancocas Creek is approximately 15 miles upstream from Hainesport and approximately 18 miles upstream from the Delaware River. The stream gage on the North Branch Rancocas Creek is approximately 25 miles upstream from the Delaware River.

The peak stage of the South Branch Rancocas Creek at Vincentown at 0815 hours on July 13 is close to the time of low tide at Delaware River at Burlington, 0800 hours, and to the NOAA-predicted time of low tide for the South Branch Rancocas Creek at Hainesport, 0923 hours. The high tide on the Delaware River at Burlington occurred at 1215 hours, and the corresponding predicted high tide for South Branch Rancocas Creek at Hainesport was at 1446 hours.

The peak stage at USGS stream gage North Branch Rancocas Creek at Pemberton occurred at 0130 hours on July 14. The duration of the peak was considerably longer than the recorded peak on the South Branch Rancocas Creek, indicative of the larger drainage area at Pemberton. The peak spanned several high tides recorded on the Delaware River at Burlington.

The high-tide elevations recorded at the Delaware River at Burlington tide gage were 6.66, 4.94, and 6.14 feet above NGVD of 1929 for the period July 12-14, 2004 (fig. 8). These stream elevations are only about 1 foot above the monthly mean high tide for July 2004. The tides for July 12-14 were not extraordinarily high.

Regardless of the timing of recorded high and low tides with peak river stages, neither hydrograph for the North and South Branches of the Rancocas demonstrated an effect of tidal fluctuations during the peaks of streamflow. The magnitude of the tide was not great enough to have a substantial effect on the flooded streams.

Ground-water conditions

Ground-water levels are monitored throughout the state by the USGS. Three wells with continuous-record ground-

water monitors within the study area were included in the study (fig. 2; listed below). The hydrographs of those wells are shown in figure 9 (Jones, 2005).

| Well number | Well name | Site identification number |
|-------------|----------------------------|----------------------------|
| 05-1467 | Rancocas St Pk MW3 | 395928074502701 |
| 05-1528 | McDonalds Branch 2 | 395243074305501 |
| 05-1538 | McDonalds Branch 2 Shallow | 395244074305501 |

The first well is located in Rancocas State Park, Hainesport Township, and is identified by the USGS as well number 05-1467. This well taps the Englishtown aquifer system of Cretaceous age. The well is 14 feet deep and is screened from 9 to 14 feet below land surface. Land surface is 17 feet above NGVD of 1929.

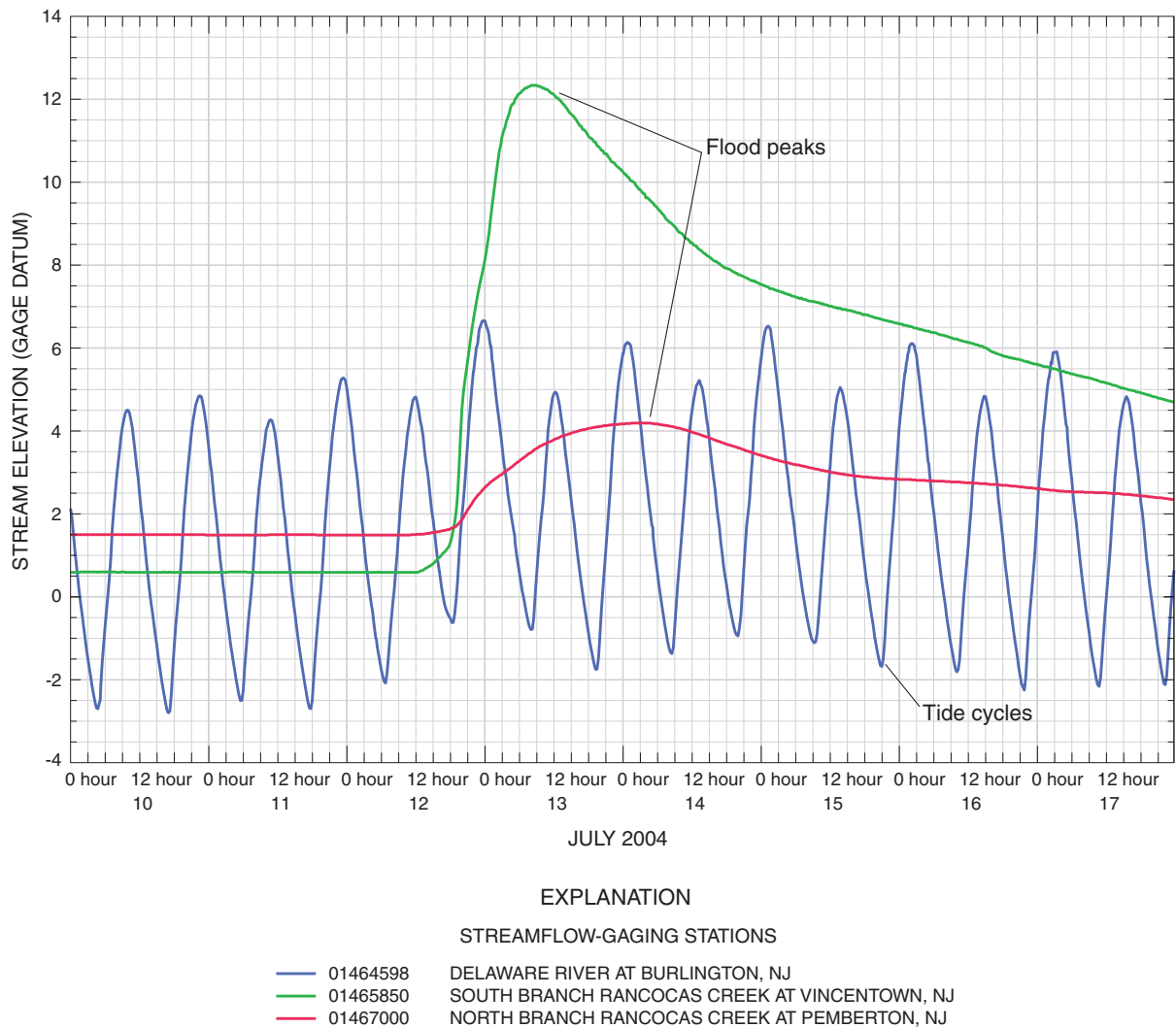


Figure 8. Tide cycles on the Delaware River and stream elevations on the North and South Branches of the Rancocas Creek at Pemberton and Vincentown, New Jersey, July 10-17, 2004.

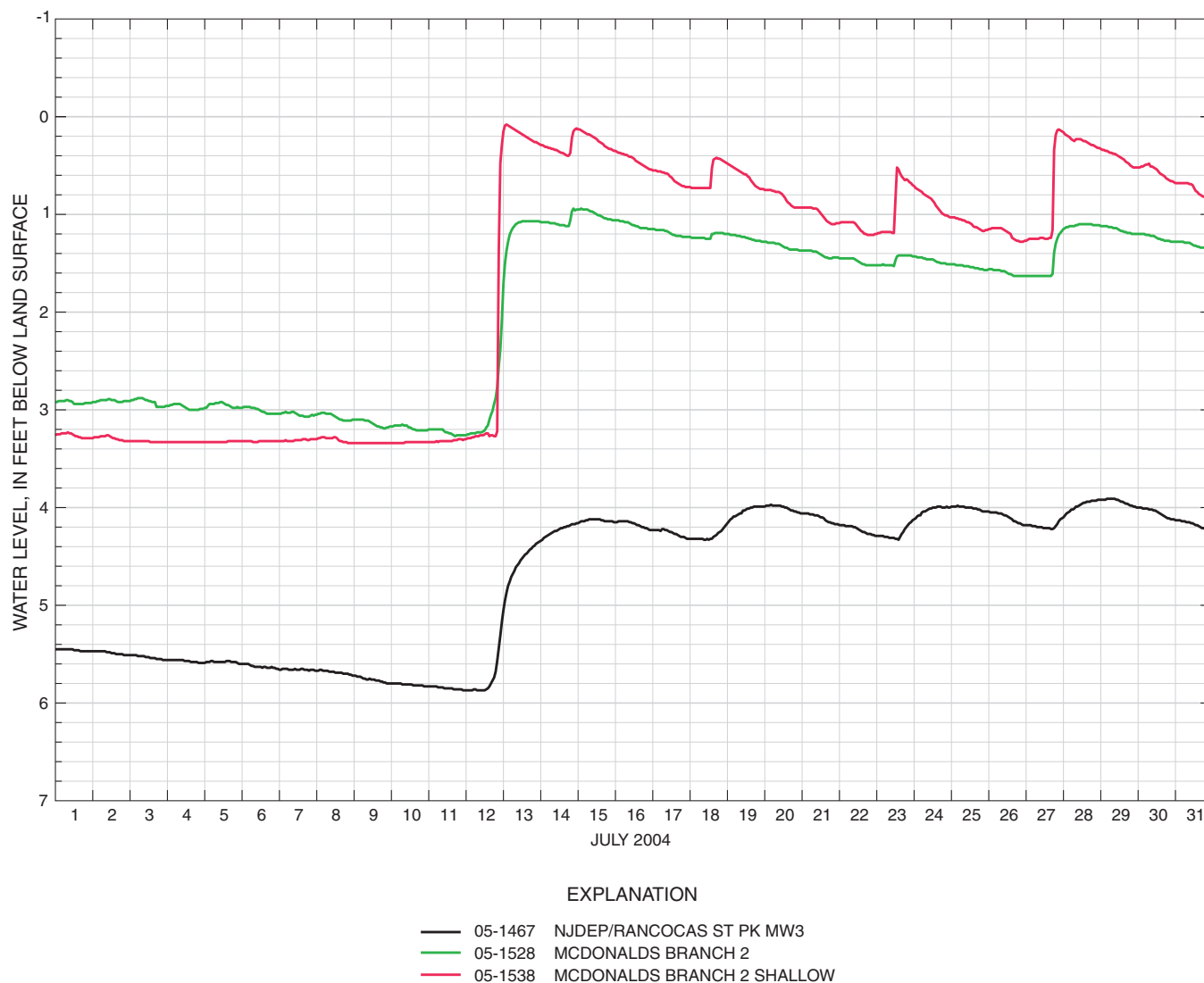


Figure 9. Water levels in three wells in the Rancocas Creek Basin, New Jersey, July 1-31, 2004.

The second well is located in Brendan T. Byrne State Forest, Woodland Township, and is identified as well number 05-1528. This well taps the Kirkwood-Cohansey aquifer system of Miocene age. The well is 6 feet deep and is screened from 5 to 6 feet below land surface. Land surface is 121.09 feet above NGVD of 1929.

The third well also is located in Brendan T. Byrne State Forest, Woodland Township, approximately 100 feet north of the second well (well number 05-1528) and is identified as well number 05-1538. This well also taps the Kirkwood-Cohansey aquifer system of Miocene age, but is 5.3 feet deep and is screened from 1.3 to 3.3 feet below land surface. Land surface is 121.22 feet above NGVD of 1929.

The water levels in the three wells were relatively low at the beginning of July 2004 because of the lack of substantial precipitation. Less than an inch of rain fell on July 5, and the precipitation did not reach the aquifers because no noticeable

rise in the water levels was evident on July 5 (fig. 9). After rain began to fall on July 12, the ground-water levels started to rise substantially in the evening hours of July 12. The ground became saturated and water levels rose more than 3 feet, almost to land surface, at the shallow well in Brendan T. Byrne State Forest (well number 05-1538). Once the ground was saturated, the lighter precipitation that occurred after July 14 caused the ground-water levels to rise quickly. Less than an inch of rain fell on July 23 producing a considerable rise in the water level of approximately 0.7 feet, which is contrary to the water level response from the similar rainfall of July 5 mentioned above.

The low ground-water levels prior to July 12 allowed the unsaturated ground to absorb some of the rain that fell. Had the ground-water levels been at a higher level prior to the precipitation of July 12, flooding in the study area could have been greater.

Historical Context

Three previous major floods were recorded in southern New Jersey in 1938, 1939, and 1940. Five of the surface-water gages outside the study area (table 5) that were in operation at the time of the 1938-40 floods recorded peak-of-record elevations and flows resulting from the three prior events. Within the affected area of the 2004 flood, only the North Branch Rancocas Creek at Pemberton continuous stream gage (NBR5, app. 1-8) was in operation at the time of the 1938-40 floods.

Streamflow elevations and discharges for all four events at the Pemberton stream gage are listed in table 6. The recorded peak-elevation for the 2004 event was only slightly higher than that for the 1940 event, but was slightly lower than those for the 1938 and 1939 events. However, flow was from 6 to 24 percent greater during the 2004 flood than the three previous events. Prior to August 1951, the gage was located approximately 900 feet downstream from its current location on Hanover Street. A dam was built midway between the previous and current sites after the 1940 flood.

The 1940 flood is most similar to the 2004 flood. The 1940 storm was an isolated, 12-hour rainfall with intense rain in the Rancocas Basin and dam failures in the upper reaches of the Southwest Branch Rancocas Creek. The 1939 storm was a 15-hour event, with heavy rainfall generally centered southeast of the 2004 study area, outside of the Rancocas Creek, Cooper River, and Pennsauken Creek Basins. The 1938 storm was the result of a hurricane and lasted for approximately 5 days (U.S. Army Engineer District, Philadelphia, 1967).

In the Rancocas Creek Basin, five of the study sites for which peak elevations were determined for the 2004 flood corresponded to locations documented for the 1940 flood (table 7). Peak flood elevations were considerably higher on the South, Southwest, and North Branches of the Rancocas Creek during the flooding of 1940 than in July 2004. A flood control project was completed in 1944 by the U.S. Army Corps of Engineers on the North Branch Rancocas Creek, upstream and downstream from Pine Street (NBR1a) in Mount Holly (app. 1-8).

Table 6. Peak stream elevations and flows on the North Branch Rancocas Creek at Pemberton, New Jersey, for four major floods.

[ft³/s, cubic feet per second; NGVD 29, National Geodetic Vertical Datum of 1929; NAVD 88, North American Vertical Datum of 1988; ---, no data available]

| North Branch Rancocas Creek at Pemberton, N.J. (NBR5 / 01467000) | | | | | |
|--|---|----------------------------------|--|------------------------------------|--------------------------------------|
| Flood date | Stream gage located 900 feet downstream from Hanover Street (1921-51) | | Stream gage located on downstream side of Hanover Street (1951-2004) | | Peak streamflow (ft ³ /s) |
| | Elevation, in feet above NGVD 29 | Elevation, in feet above NAVD 88 | Elevation, in feet above NGVD 1929 | Elevation, in feet above NAVD 1988 | |
| August 22, 1939 | 35.21 | 33.98 | --- | --- | 1,730 |
| September 22, 1938 | 35.42 | 34.19 | --- | --- | 1,680 |
| September 1, 1940 | 34.30 | 33.07 | --- | --- | 1,480 |
| July 13, 2004 | ¹ 34.72 | ¹ 33.49 | 35.38 | 34.15 | 1,840 |

¹ High-water marks were flagged and surveyed at the previous stream gage location for the 2004 flood. A dam was rebuilt midway between the previous and current stream gage locations.

Table 7. Peak stream elevations on the Rancocas Creek, south-central New Jersey, September 1, 1940, and July 12-13, 2004.

| Location | Elevation, in feet above NGVD 29 | | | Elevation, in feet above NAVD 88 | | |
|------------------------------------|----------------------------------|-----------|------------|----------------------------------|-----------|------------|
| | September 1940 | July 2004 | | September 1940 | July 2004 | |
| | | Upstream | Downstream | | Upstream | Downstream |
| South Branch Rancocas Creek | | | | | | |
| SBR1 (Main Street) | ¹ 17.43 | 15.4 | 15.2 | ¹ 16.26 | 14.2 | 14.0 |
| SBR0 (Marne Hwy) | ¹ 12.76 | 11.2 | 10.7 | ¹ 11.61 | 10.1 | 29.6 |
| Southwest Branch Rancocas Creek | | | | | | |
| SWB2 (Church Street) | ¹ 32.37 | 30.6 | 30.1 | ¹ 31.18 | 29.4 | 28.9 |
| North Branch Rancocas Creek | | | | | | |
| NBR3 (U.S. Route 206) | ¹ 26.82 | 24.8 | 24.1 | ¹ 25.62 | 23.6 | 22.9 |
| NBR1 (at Pine Street) ² | ¹ 16.23 | 11.7 | 11.7 | ¹ 15.06 | 10.5 | 10.5 |

¹ The locations of the elevations were not defined as upstream or downstream.

² The U.S. Army Corps of Engineers completed a flood control project in 1944, upstream and downstream from this site in Mount Holly, N.J.

Flood Damage

The July 12-13, 2004, flood caused damage to many homes, businesses, public lands, and infrastructure throughout communities in Burlington and Camden Counties. Some of the reported effects of the storm are listed below.

- Property damage from the flood was estimated at \$50 million (National Ocean and Atmospheric Administration, 2005a).
- The combination of the dam failures and stream flooding led to the evacuation of about 760 residents; the destruction of seven homes in Lumberton and Southampton Townships in Burlington County; major flood damage to approximately 200 homes; flood damage to approximately 1,000 homes; the closing of 25 major roads, including the New Jersey Turnpike and New Jersey State Routes 70 and 73; the contamination of drinking water and failure of sewage systems; and serious damage or destruction of 14 bridges (National Climatic Data Center, 2005a).
- Divers from the U.S. Coast Guard closed the valves of a 10,000-gallon tank belonging to a Vincentown oil company. The tank had separated from its moorings (Linkous, 2004).
- Many small boats and hovercraft were used to rescue people, several of whom were stranded on rooftops.
- No casualties were reported.
- Days after the flood, a temporary bridge over Friendship Creek was constructed on State Route 70, a main roadway for visitors to the New Jersey shoreline.
- Governor James E. McGreevy announced (after this event) that \$30 million would be added to the \$95 million state bond issue for restoration of dams in New Jersey. The \$95 million state bond issue was approved November 2003 for restoration of approximately 360 dams that had been labeled by state inspectors as needing repair (Holl, 2004).

Flood Management Upgrades

Projects for improving flood management in Burlington and Camden County are listed in the report, "Findings of the Interagency Waterway Infrastructure Improvement Task Force, FEMA-1530 DR NJ, October 2004" (New Jersey Office of Emergency Management, 2006). In response to a need identified by that investigation, the USGS and Burlington County agreed to upgrade satellite telemetry equipment at three stream gages and to install new near real-time surface water and precipitation gages in the Rancocas Creek Basin.

Streamflow and precipitation data are now transmitted by satellite hourly instead of every 4 hours from gages on the North Branch Rancocas Creek at Pemberton (NBR5) and Greenwood Branch at New Lisbon (GRE1). A telephone modem and phone line were installed at the stream gage on the South Branch Rancocas Creek at Vincentown (SBR3). A near real-time precipitation gage and stream gage were placed on the Southwest Branch Rancocas Creek at Medford (SWB4).

The equipment upgrades provide more frequent information on stream conditions. The new stream gage provides data for a stream previously unmonitored. Water managers, local officials, and the public can access similar data through the USGS web site at <http://nj.usgs.gov>.

Summary

An isolated, nonhurricane-related, 15-hour rainfall deluged south-central New Jersey on July 12-13, 2004. As much as 13 inches of rain was reported in south-central Burlington County, and more than 7 inches of rain was reported in northern Camden County. As a result of the storm, 17 dams failed, and 28 dams were damaged. High-water conditions immediately followed, with extensive damage to private and public property. The most substantial effects were confined within the Rancocas Creek, Cooper River, and Pennsauken Creek Basins, which are tributaries to the Delaware River. The U.S. Geological Survey (USGS), in cooperation with the Federal Emergency Management Agency (FEMA), conducted a study to collect, compute, and compile flood-related data in the three affected basins subsequent to the event.

The largest drainage area of the three affected basins is that of the Rancocas Creek Basin (347 mi²). The South Branch Rancocas Creek subbasin sustained the most widespread flooding; many peak-of-record flood elevations and streamflows were recorded. Flooding was more prominent in the Rancocas Creek Basin than in the Cooper River and Pennsauken Creek Basins in part because of numerous dam failures and higher rainfall totals in the headwaters of the basin. More than 80 percent of the documented flood elevations exceeded the FEMA-projected 100-year flood elevations. However, the flood elevations recorded in the Rancocas Basin in July 2004 did not exceed elevations recorded for a similar flood in September 1940.

Two peak streamflows determined for the South Branch Rancocas Creek subbasin had recurrence intervals greater than 100 years. One peak streamflow determined in the North Branch of Rancocas Creek subbasin had a 40-year recurrence interval; however, the peak streamflow was greater than those determined for three previous floods that occurred during 1938-40.

Peak-of-record elevations and streamflows also occurred in the Cooper River and Pennsauken Creek Basins. The periods of record for these basins did not begin until 1963 and 1967, respectively. Less than 50 percent of the documented

flood elevations exceeded the FEMA-projected 100-year flood elevations; however, the recurrence intervals for two of the three peak streamflows determined in the Cooper River Basin exceeded 100 years. One peak streamflow in the Pennsauken Creek Basin was equivalent to a 75-year event.

Tidal and ground-water conditions did not exacerbate the high-water conditions. Although the high tide on the Delaware River on July 12-13 was approximately 1 foot above the monthly mean high tide, it did not contribute to high-water conditions. Flooding in the tidal parts of the reach could have been more severe had the magnitude of the tide been greater. Ground-water levels in the affected basins also were low, as reflected in the continuous records of water levels in wells in the study area. Much of the precipitation was absorbed into the ground, lessening the magnitude of the flood.

Acknowledgments

The authors gratefully acknowledge the following USGS employees for their contribution to the fieldwork that made this report possible: Guerino Centinaro, Jonathan Dillow, John Dudek, Kenneth Hayes, Thomas Moffett, Brian Painter, Peter Reilly, Robert Reiser, Robert Schopp, Jason Shvanda, David Stedfast, Kathryn Tuers, Andrew Watson, and Blaine White. The authors also recognize Kara Watson, USGS, who had an integral role in creating the maps included in the report, and William Ellis, USGS, who prepared the illustrations for publication. The authors are grateful to Harold Bozarth, Jr., Office of the County Engineer in Burlington County and Frederick Czepiga, New Jersey Geodetic Survey, who provided benchmark information.

References Cited

- Benson, M.A. and Dalrymple, T., 1967, General field and office procedures for indirect discharge measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter A1, 30 p.
- Centinaro, G. L., White B.T., Hoppe H. L., Dudek J. F., Protz A. R., Reed T. J., Shvanda J. C., and Watson A. F., 2005, Water-resources data for New Jersey-Water Year 2004, volume 1. Surface-Water Data: U.S. Geological Survey Water-Data Report NJ-04-01, 386 p.
- Federal Emergency Management Agency, 1979a, Flood Insurance Study, Township of Pemberton, Burlington County, New Jersey: Federal Emergency Management Agency, Federal Insurance Administration, panels 01P, 02P, 05P, 06P, and 07P.
- _____, 1979b, Flood Insurance Study, Township of Southampton, Burlington County, New Jersey: Federal Emergency Management Agency, Federal Insurance Administration, panels 02P, 03P, 04P, 14P, and 15P.
- _____, 1980, Flood Insurance Study, Borough of Medford Lakes, Burlington County, New Jersey: Federal Emergency Management Agency, panels 01P and 02P.
- _____, 1983a, Flood Insurance Study, Township of Lumberton, Burlington County, New Jersey: Federal Emergency Management Agency, panels 01P, 02P, and 03P.
- _____, 1983b, Flood Insurance Study, Township of Medford, Burlington County, New Jersey: Federal Emergency Management Agency, panels 01P, 02P, 03P, 09P, 11P, 12P, 13P, 15P, and 16P.
- _____, 1992a, Flood Insurance Study, Township of Cherry Hill, Camden County, New Jersey: Federal Emergency Management Agency, panels 03P, 04P, 05P, and 11P.
- _____, 1992b, Flood Insurance Study, Township of Tabernacle, Burlington County, New Jersey: Federal Emergency Management Agency, panel 01P.
- _____, 1995, Flood Insurance Study, Township of Evesham, Burlington County, New Jersey: Federal Emergency Management Agency, panel 04P.
- _____, 1996, Flood Insurance Study, Township of Moorestown, Burlington County, New Jersey: Federal Emergency Management Agency, panel 02P.
- _____, 2004, Flood Insurance Rate Maps, FIRMettes. (Accessed July 2004, at URL <http://www.msc.fema.gov>)
- Holl, John, 2004, In flooded New Jersey towns, the cleanup begins: New York, New York Times, July 15, 2004.
- Hulsing, H., 1967, Measurement of peak discharge at dams by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter A5, 29 p.
- Jones, W.D., 2005, Water resources data for New Jersey-Water Year 2004, volume 2. Ground-Water Data: U.S. Geological Survey Water-Data Report NJ-03-02, 232 p.
- Kennedy, E.J., 1984, Discharge ratings at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter A10, 35 p.
- Linkous, Jeff, 2004, Southern N.J. floods prompt call for federal aid: Pleasantville, N.J., Atlantic City Press, July 14, 2004.
- Ludlum, David L, 1983, The New Jersey weather book, Rutgers University Press, p 249.

- Matthai, H.F., 1967, Measurement of peak discharge at width contractions by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter A4, 44 p.
- National Geodetic Survey, 2004, NGS Datasheet Page, accessed August 2004, at URL <http://www.ngs.noaa.gov/cgi-bin/datasheet.prl>
- National Oceanic and Atmospheric Administration, 2005a, National Climatic Data Center, U.S. Storm Events Database, Event Record Details, Flood, July 2004, New Jersey, accessed May 16, 2005, at URL <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms>
- _____, 2005b, National Climatic Data Center, New Jersey Climate Summary, unpublished data accessed on May 16, 2005 at URL <http://ncdc.noaa.gov/oal/climate/research/cag3/nj.html>
- New Jersey Department of Environmental Protection, 2005, Dam Safety and Flood Control, Grants and Loans, accessed June 21, 2005, at URL <http://www.nj.gov/dep/damsafety/engineer.htm>
- _____, 2000, Land use/land cover and impervious surfaces for watershed management areas 18 and 19, 1995/97, data accessed April 2000 at URL <http://www.state.nj.us/dep/gis/lulc95shp.html>
- New Jersey Office of Emergency Management, 2006, Findings of the Interagency Waterway Infrastructure Improvement Task Force, accessed on January 4, 2006, at URL <http://www.state.nj.us/njoem/pdf/df-report.pdf>
- U.S. Army Engineer District, Philadelphia, 1967, Flood Plain Information: Report on Rancocas Creek, Burlington County, New Jersey, U.S. Army Engineer District, Philadelphia, Corps of Engineers, 38p.
- U.S. Department of Housing and Urban Development, 1976, Flood Insurance Study, Borough of Haddonfield, Camden County, New Jersey: U.S. Department of Housing and Urban Development, Federal Insurance Administration, panel 01P.
- _____, 1978a, Flood Insurance Study, Borough of Lawnside, Camden County, New Jersey: U.S. Department of Housing and Urban Development, Federal Insurance Administration, panel 01P.
- _____, 1978b, Flood Insurance Study, Township of Voorhees, Camden County, New Jersey: U.S. Department of Housing and Urban Development, Federal Insurance Administration, panels 01P, 07P, and 13P.
- _____, 1979a, Flood Insurance Study, Township of Mount Holly, Burlington County, New Jersey: U.S. Department of Housing and Urban Development, Federal Insurance Administration, panels 01P and 02P.
- _____, 1979b, Flood Insurance Study, Borough of Pemberton, Burlington County, New Jersey: U.S. Department of Housing and Urban Development, Federal Insurance Administration, panel 01P.
- _____, 1979c, Flood Insurance Study, Township of Eastampton, Burlington County, New Jersey: U.S. Department of Housing and Urban Development, Federal Insurance Administration, panel 02P.
- U.S. Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency, Bulletin 17-B of the Hydrology Subcommittee: Reston, Virginia, U.S. Geological Survey, Office of Water Data Coordination, 183 p.

Appendix 1—Stream reaches in the study area

Appendix 1 contains:

- Maps showing locations of stream reaches and study sites, precipitation gages with values, and compromised dams within the study area
- Descriptions of study sites (lat, latitude; long, longitude)
- Selected photographs of flooding. (All photographs taken by USGS field crews.)

Appendix 1. Stream reaches in the study area.

| | | |
|-----|--|----|
| 1-1 | Index map of stream reaches and basins | 31 |
|-----|--|----|

Rancocas Creek Basin

| | | |
|-----|--|----|
| 1-2 | South Branch Rancocas Creek | 32 |
| 1-3 | Friendship Creek..... | 36 |
| 1-4 | Haynes Creek..... | 38 |
| 1-5 | Southwest Branch Rancocas Creek | 40 |
| 1-6 | Ballinger Run..... | 42 |
| 1-7 | Barton Run and Barton Run tributary..... | 44 |
| 1-8 | North Branch Rancocas Creek | 46 |
| 1-9 | Greenwood Branch | 50 |

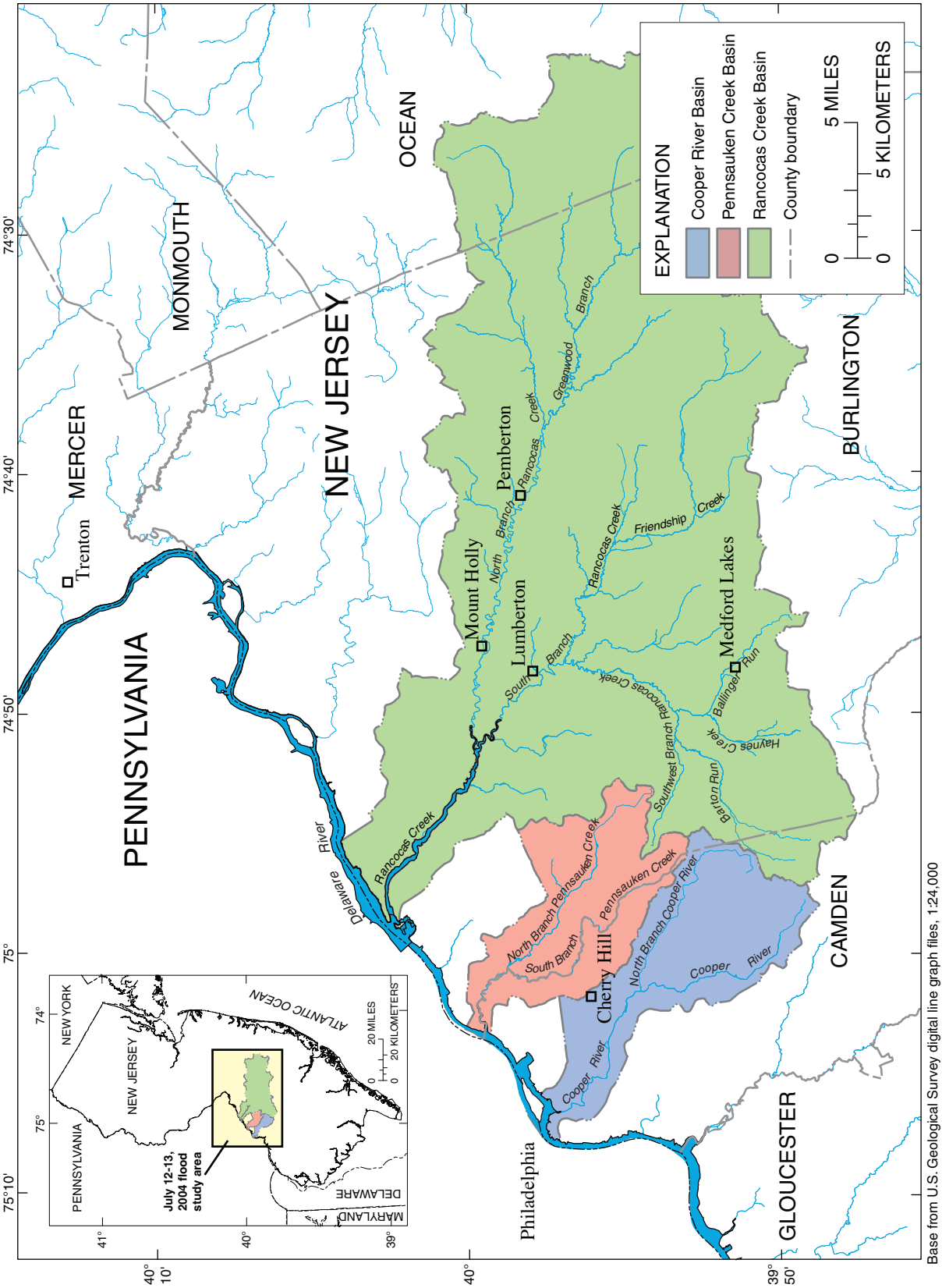
Pennsauken Creek Basin

| | | |
|------|------------------------------------|----|
| 1-10 | North Branch Pennsauken Creek..... | 52 |
| 1-11 | South Branch Pennsauken Creek..... | 54 |

Cooper River Basin

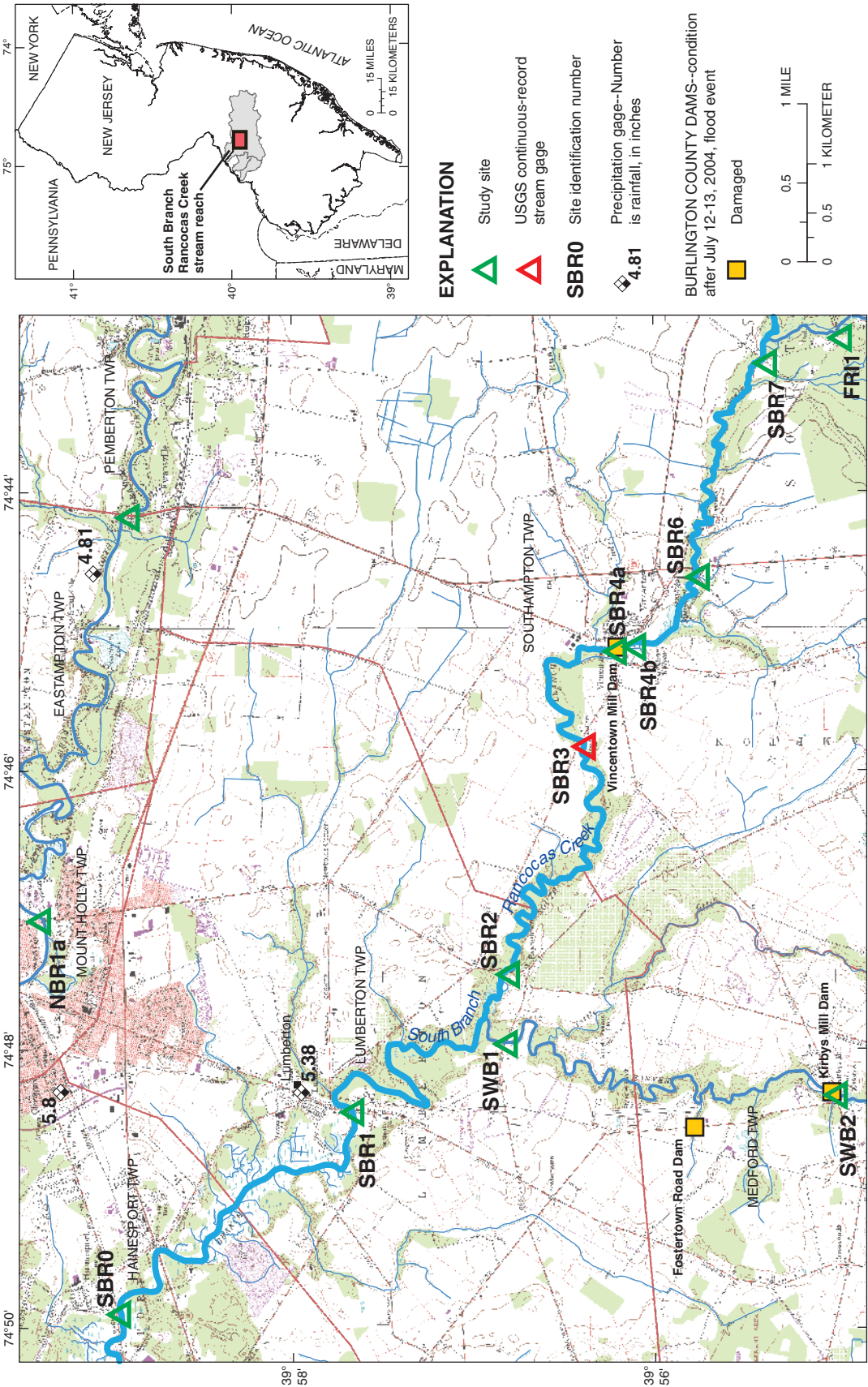
| | | |
|------|--------------------------------|----|
| 1-12 | Cooper River..... | 56 |
| 1-13 | North Branch Cooper River..... | 58 |

Appendix 1-1



Index map of stream reaches and basins in which flood elevations and discharges were determined for the Burlington and Camden Counties, New Jersey, flood of July 12-13, 2004.

Appendix 1-2



Locations of South Branch Rancocas Creek stream reach, study sites, precipitation gages with values, and dams associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-2—Continued.

| South Branch Rancocas Creek (tributary to Rancocas Creek) | | |
|---|----------------------|--|
| Burlington County | Southampton Township | <p>SBR7: 01465835 South Branch Rancocas Creek at Retreat, N.J. Lat 39°55'23" Long 74°43'05", at bridge on Ridge Road in Retreat, N.J. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: one poor mark, 5 feet upstream on right bank; one fair mark, 10 feet downstream on left bank. Marks referenced to datum using National Geodetic Survey Monument BC12 (PID: AB8731).</p> |
| | | <p>SBR6: (not an existing USGS site) Lat 39°55'45" Long 74°44'37", at bridge on Hilliards Bridge Road in Vincentown, N.J. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: two fair to poor marks, 2 and 8 feet upstream on left and right bank, respectively; two fair marks, 5 and 10 feet downstream on left and right bank, respectively. Marks referenced to datum using New Jersey Geodetic Survey Monument 14872X.</p> |
| | | <p>SBR4b: (not an existing USGS site) Lat 39°56'07" Long 74°45'07", at Vincentown Mill Dam, at Race Street in Vincentown, N.J. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: one good mark, 50 feet upstream from dam on left bank. Marks referenced to datum using RM3 from FEMA Flood Insurance Study, Township of Southampton (1983b).</p> |
| | | <p>SBR4a: 01465840 South Branch Rancocas Creek at Church Road at Vincentown, N.J. Lat 39°56'13" Long 74°45'09", at bridge on Church Road (County Route 616) in Vincentown. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: two fair marks, 40 and 50 feet upstream on left bank, and one good mark, 10 feet upstream on right bank; two fair marks 40 and 50 feet downstream, on left and right banks, respectively. Marks referenced to datum using RM3 from FEMA Flood Insurance Study, Township of Southampton (1983b).</p> |
| | | <p>SBR3: 01465850 South Branch Rancocas Creek at Vincentown, N.J. (continuous gage) Lat 39°56'22" Long 74°45'50", at bridge on Landing Street (County Route 641), in Vincentown, N.J. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: one good mark on upstream bridge face verified stream elevation recorded at continuous gage 30 feet upstream on left bank; one mark, 200 feet downstream on left bank. Marks referenced to datum using gaging station levels.</p> |
| | Lumberton Township | <p>SBR2: 01465854 South Branch Rancocas Creek at Eayrestown, N.J. Lat 39°56'49" Long 74°47'28", at bridge on Eayrestown-Newbolds Road in Eayrestown, N.J. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: one good mark, 10 feet upstream on right bank; one good mark, 50 downstream on left bank. Marks were referenced to datum using New Jersey Geodetic Survey Monument 27285.</p> |
| | | <p>SBR1: (not an existing USGS station) Lat 39°57'40" Long 74°48'27", at bridge on Main Street (County Route 541) in Lumberton, N.J. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: two fair marks, 10 and 20 feet upstream on the right and left bank, respectively; one fair mark, 50 feet downstream on right bank. Marks were referenced to datum using New Jersey Geodetic Survey Monument 27284.</p> |
| | Hainesport Township | <p>SBR0: 01465917 South Branch Rancocas Creek at Rancocas Heights, N.J. Lat 39°58'57" Long 74°49'54", at bridge on Ridge Road (County Route 537) in Rancocas Heights, N.J. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: one fair mark, 20 feet upstream on right bank; two fair to good marks, 50 and 70 feet downstream on left and right bank, respectively. Marks were referenced to datum using New Jersey Geodetic Survey Monument 27238.</p> |

Appendix 1-2—Continued.



High-water mark on upstream left bank of South Branch Rancocas Creek at Lumberton, N.J. (SBR1).

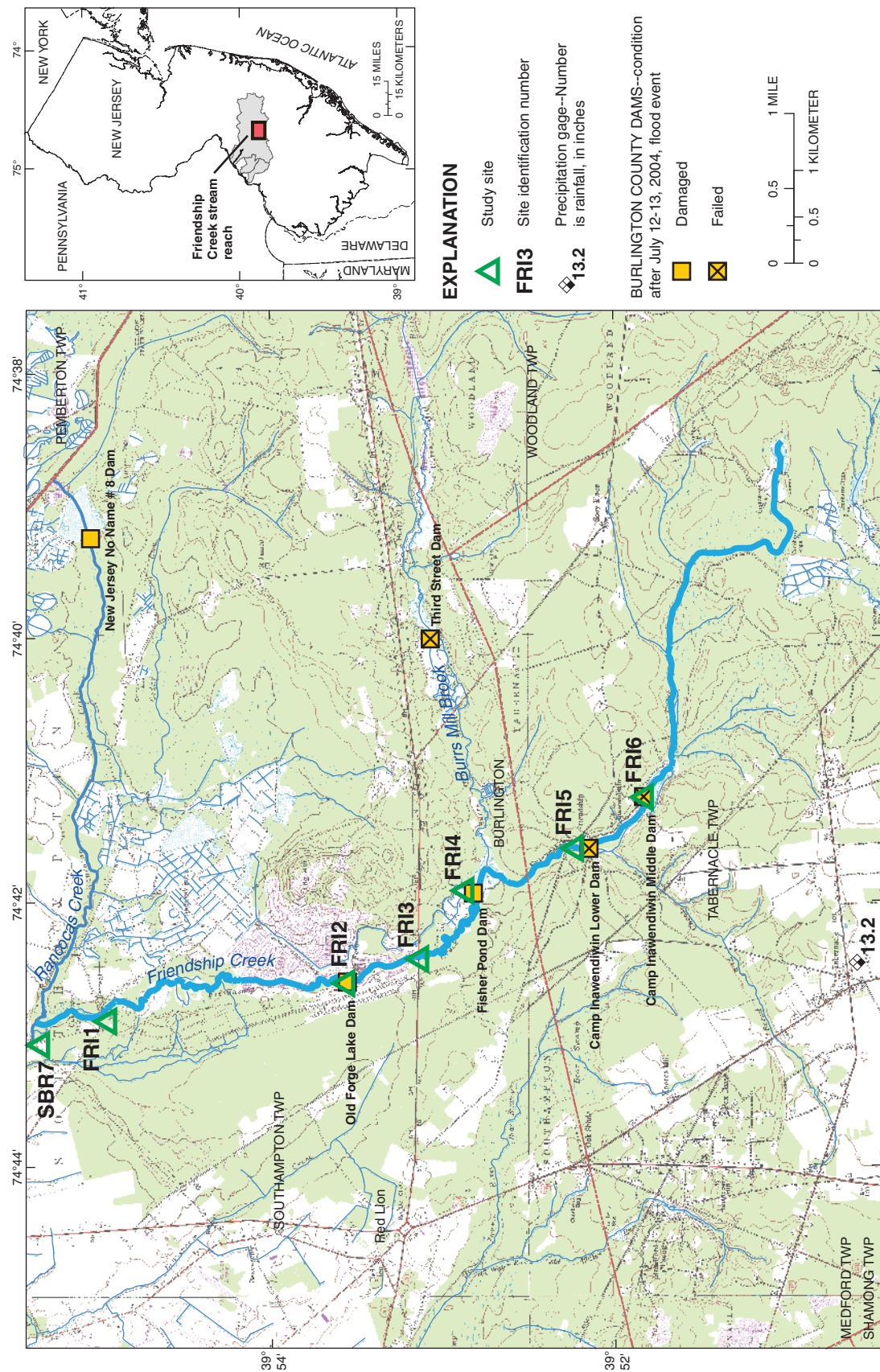


Former Lumberton Inn, Lumberton, N.J. Red arrow is height of 1940 flood; blue arrow is height of 2004 flood (SBR1).



Damage to Hillards Bridge Road, at South Branch Rancocas Creek, Vincentown, N.J. (SBR6).

Appendix 1-3



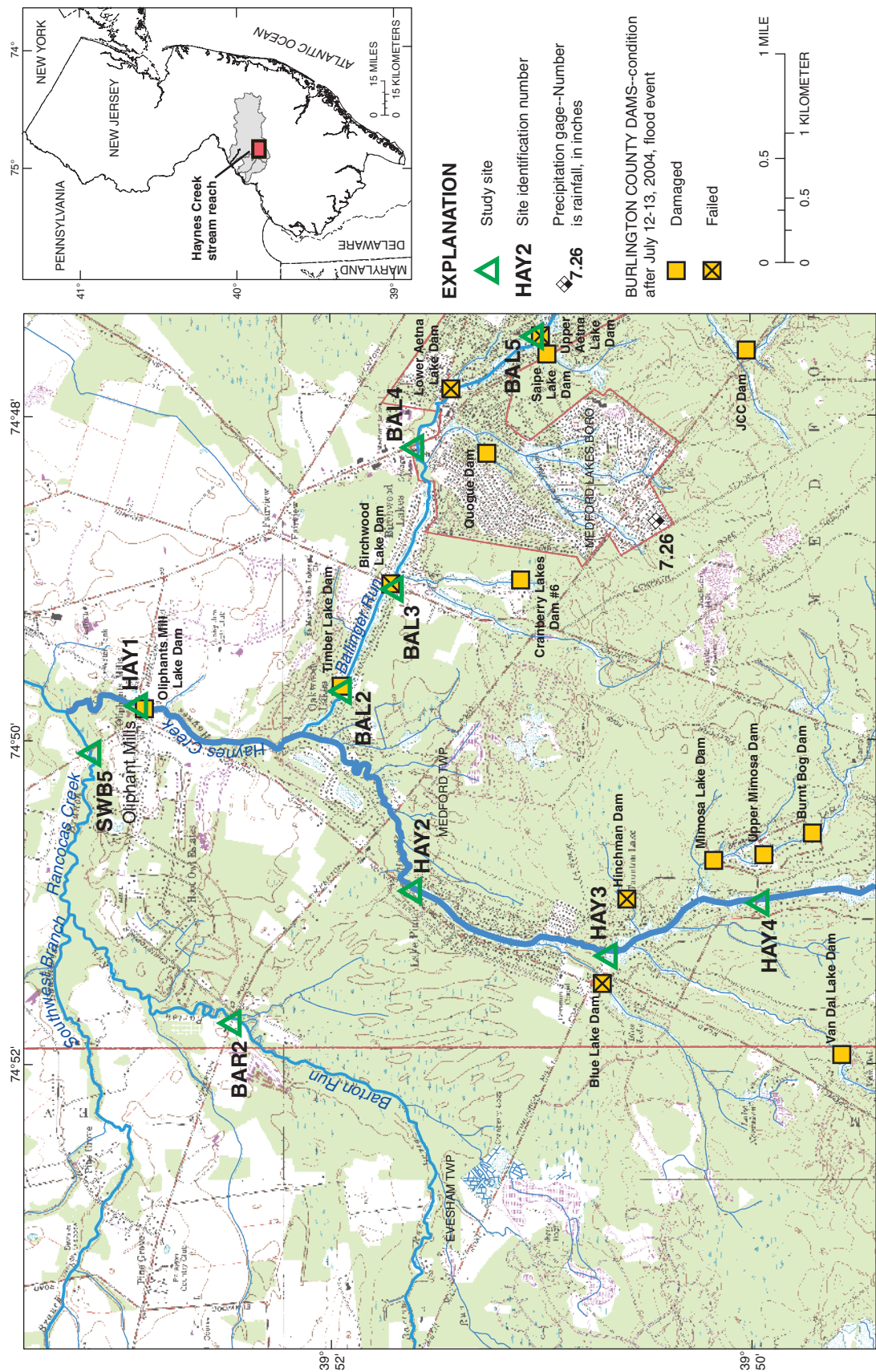
Base from U.S. Geological Survey Digital Raster Graphics, 1:24,000, Universal Transverse Mercator projection, NAD83

Location of Friendship Creek stream reach, study sites, precipitation gage with value, and dams associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-3—Continued.

| Friendship Creek (tributary to South Branch Rancocas Creek) | | |
|---|----------------------|--|
| Burlington County | Tabernacle Township | <p>FRI6: (not an existing USGS station) Lat 39°51'50" Long 74°41'13", at Camp Inawendiwin Middle Dam in Friendship, N.J. Indian Mills USGS 7.5' Topographic Quadrangle High-Water Marks: one poor mark, 300 feet upstream on right bank; two good to fair marks, 40 and 100 feet downstream and right and left bank, respectively. Marks referenced to datum using RM2 from FEMA Flood Insurance Study, Township of Tabernacle (1992b).</p> |
| | | <p>FRI5: 01465807 Friendship Creek at Friendship, N.J. Lat 39°52'15" Long 74°41'36", at bridge on Powell Place Road. Indian Mills USGS 7.5' Topographic Quadrangle High-Water Marks: two good to fair marks, 40 and 50 feet upstream on left and right bank, respectively; two good to poor marks, 40 and 50 feet downstream on left and right bank, respectively. Marks referenced to datum using RM2 from FEMA Flood Insurance Study of Tabernacle Township (1992b).</p> |
| | Southampton Township | <p>FRI4: (not an established USGS station) Lat 39°52'53" Long 74°41'55", at privately owned earthen dam on Steeplebush Terrace, near Red Lion, N.J. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: one poor mark, 200 feet upstream on left bank; one poor mark on tree on top of earthen dam (used in upstream average); one fair mark, 40 feet downstream on left bank. Marks referenced to datum using RM1 from FEMA Flood Insurance Study, Township of Tabernacle (1992b).</p> |
| | | <p>FRI3: 01465825 Friendship Creek near Red Lion, N.J. Lat 39°53'09" Long 74°42'26", at bridge on State Route 70 near Red Lion. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: one poor mark, 140 feet upstream on right bank; one good mark, 400 feet downstream on right bank. Marks referenced to datum using Parker-Kalon (PK) nail control station (1013.20 BASELINE) established by New Jersey Geodetic Survey for Friendship Creek Emergency Bridge Replacement Global Positioning System (GPS) Project.</p> |
| | | <p>FRI2: (not an established USGS station) Lat 39°53'34" Long 74°42'37", at Old Forge Lake Dam, at end of Gloria Lane Road, near Red Lion, N.J. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: one fair mark, 20 feet upstream on right bank; two fair marks, 60 and 75 feet downstream, on right and left banks, respectively. Marks referenced to datum using rebar with cap control station (GPS1) established by New Jersey Geodetic Survey for Friendship Creek Emergency Bridge Replacement GPS Project.</p> |
| | | <p>FRI1: 01465833 Friendship Creek at Retreat, N.J. Lat 39°54'58" Long 74°42'54", at bridge on Retreat Road in Retreat, N.J. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: one fair mark, 40 feet upstream on left bank; one poor mark, 60 downstream on left bank. Marks referenced to datum using National Geodetic Survey monument BC12 (PID: AB8731)</p> |

Appendix 1-4



Location of Haynes Creek stream reach, study sites, precipitation gage with value, and dams associated with the July 12-13, 2004, flood event, south-central New Jersey.

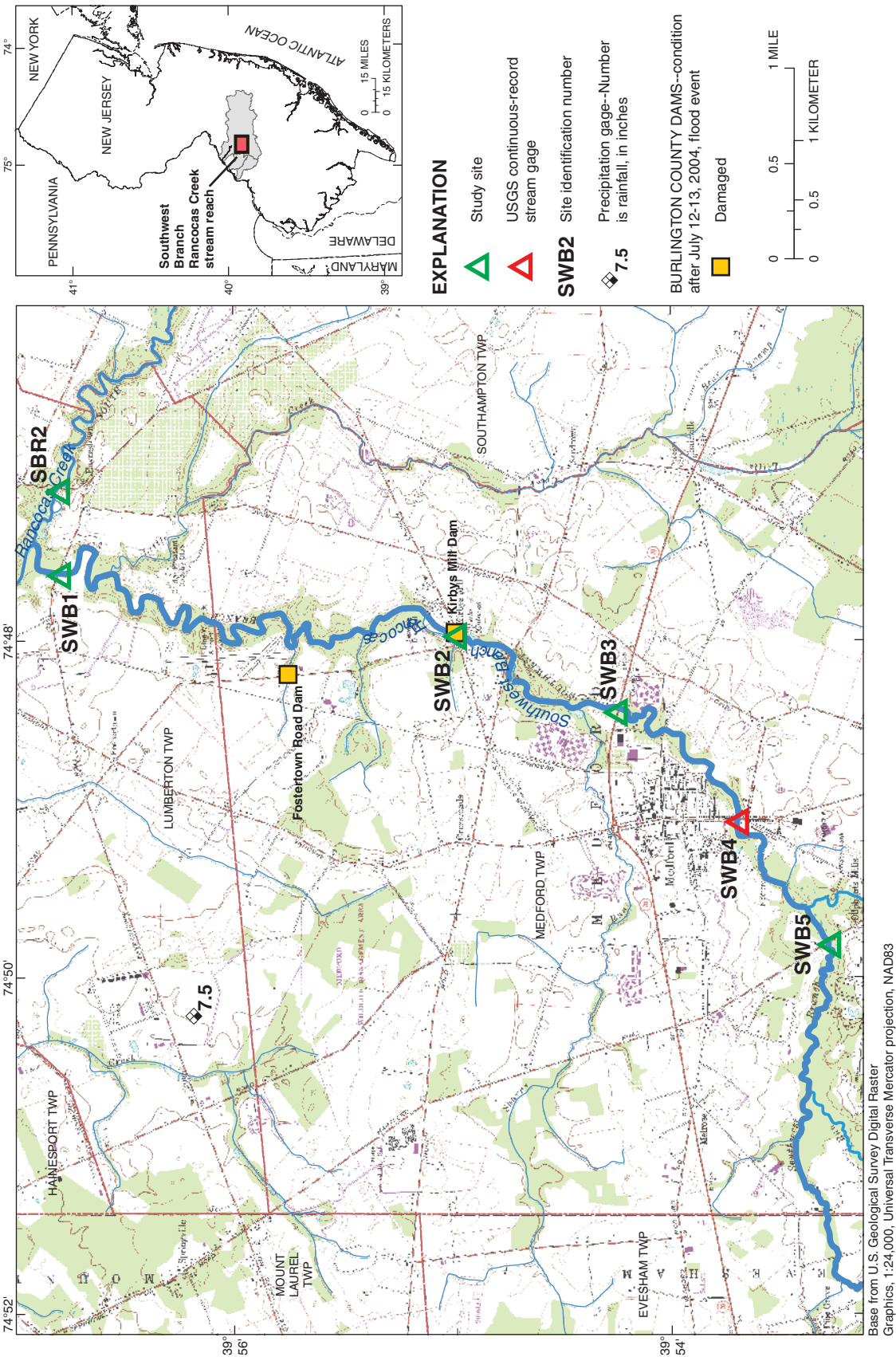
Appendix 1-4—Continued.

| Haynes Creek (tributary to Southwest Branch Rancocas Creek) | | |
|---|------------------|--|
| Burlington County | Medford Township | <p>HAY4: 0146587105 Kettle Run (Haynes Creek tributary) at Centennial Lake near Medford Lakes, N.J. Lat 39°50'31" Long 74°50'59", at bridge on Centennial Dam Road near Medford Lakes. Medford Lakes USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: one fair mark, 400 feet upstream on right bank; one fair mark, 500 feet downstream on right bank. Marks referenced to datum using Burlington County Engineering Department PK nail, station 6120.</p> |
| | | <p>HAY3: 01465872 Haynes Creek at Taunton Lakes, N.J. Lat 39°51'09" Long 74°51'16", at bridge on Breakneck Road/Taunton Lake dam in Taunton Lakes. Medford Lakes USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: one fair mark, 8 feet upstream from dam on right bank; one good mark 150 feet downstream from road, on right bank. Marks referenced to datum using RM14 from FEMA Flood Insurance Study, Township of Medford (1983b).</p> |
| | | <p>HAY2: 01465873 Haynes Creek at Lake Pine, N.J. Lat 39°51'58" Long 74°50'55", at bridge on Falls Road in Lake Pine. Medford Lakes USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: one fair mark, 200 feet upstream on right bank; one fair mark, 150 feet downstream on right bank. Marks referenced to datum using Burlington County Engineering Department station 7370.</p> |
| | | <p>HAY1: 01465878 Haynes Creek at Oliphant Mills, N.J. Lat 39°53'06" Long 74°49'55", at bridge on Himmelein Road and Pine Lake dam in Oliphant Mills. Mount Holly USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: two fair marks, each 100 feet upstream from dam; two good marks, 70 and 110 feet downstream from road, on left and right bank, respectively. Marks referenced to datum using New Jersey Geodetic Survey monument 27288.</p> |



High-water mark on downstream, left bank of Haynes Creek at Oliphant Mills, N.J. (HAY1).

Appendix 1-5

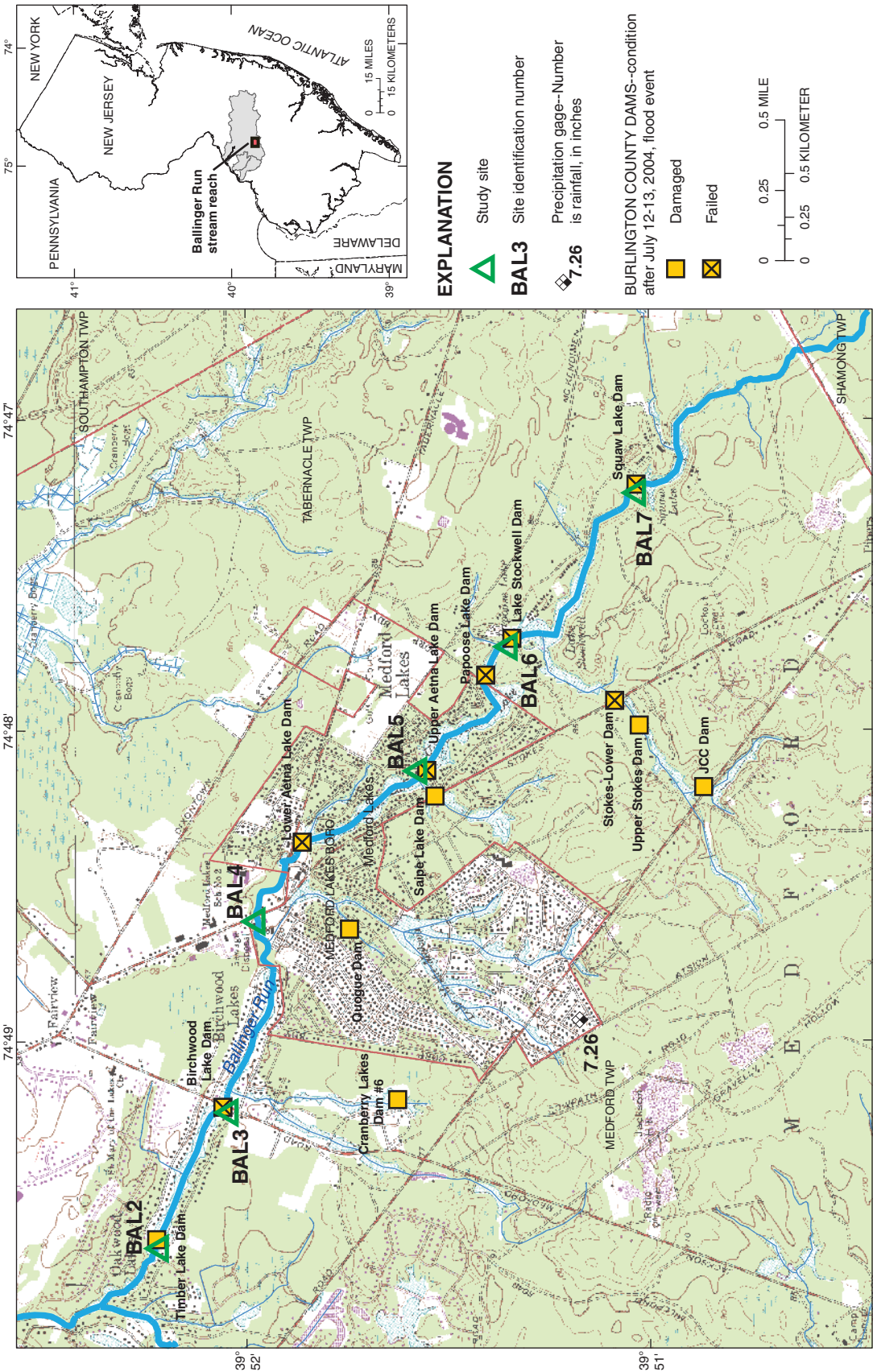


Location of Southwest Branch Rancocas Creek stream reach, study sites, precipitation gage with value, and dams associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-5—Continued.

| Southwest Branch Rancocas (tributary to South Branch Rancocas Creek) | | |
|--|--------------------|---|
| Burlington County | Medford Township | <p>SWB5: 01465870 Southwest Branch Rancocas Creek at Oliphants Mills, N.J. Lat 39°53'18" Long 74°50'10", at bridge on Hartford Road in Oliphants Mills. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: two good to poor marks, 70 and 120 feet upstream on left and right banks; two poor marks, 40 and 130 feet downstream on left and right banks, respectively. Marks referenced to datum using New Jersey Geodetic Survey monument 27288.</p> |
| | | <p>SWB4: 01465880 Southwest Branch Rancocas Creek at Medford, N.J. (crest-stage gage) Lat 39°53'43" Long 74°49'26", at bridge on South Main Street in Medford. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: a total of 27 marks were flagged within 290 feet upstream and 140 feet downstream from road for indirect computation of streamflow. The elevations given in Table 3 are averages of all upstream and downstream marks.</p> |
| | | <p>SWB3: 01465882 Southwest Branch Rancocas Creek at Route 70 at Medford, N.J. (crest-stage gage) Lat 39°54'16" Long 74°48'47", at bridge on State Route 70 (Main Street) in Medford. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: two marks, 10 and 60 feet upstream on left and right banks, respectively; two marks, 15 and 40 feet downstream on left and right banks, respectively. Marks referenced to datum using New Jersey Geodetic Survey monument 111896.</p> |
| | | <p>SWB2: 01465888 Southwest Branch Rancocas Creek at Kirbys Mill, N.J. Lat 39°55'00" Long 74°48'20", at bridge on Church Road in Kirbys Mill. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: two excellent marks, each 20 feet upstream from road, on left and right banks; two good to fair marks, 20 and 75 feet downstream from road, on right and left bank, respectively. Marks referenced to datum using RM1 from FEMA Flood Insurance Study, Township of Medford (1983b).</p> |
| | Lumberton Township | <p>SWB1: 01465900 Southwest Branch Rancocas Creek at Eayrestown, N.J. Lat 39°56'49" Long 74°47'58", at bridge on Fosterown-Eayrestown Road in Eayrestown. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 200 and 260 feet upstream on right and left banks, respectively; two excellent to good marks, 40 and 70 feet downstream left and right banks, respectively. Marks referenced to datum using New Jersey Geodetic Survey monument 27285.</p> |

Appendix 1-6

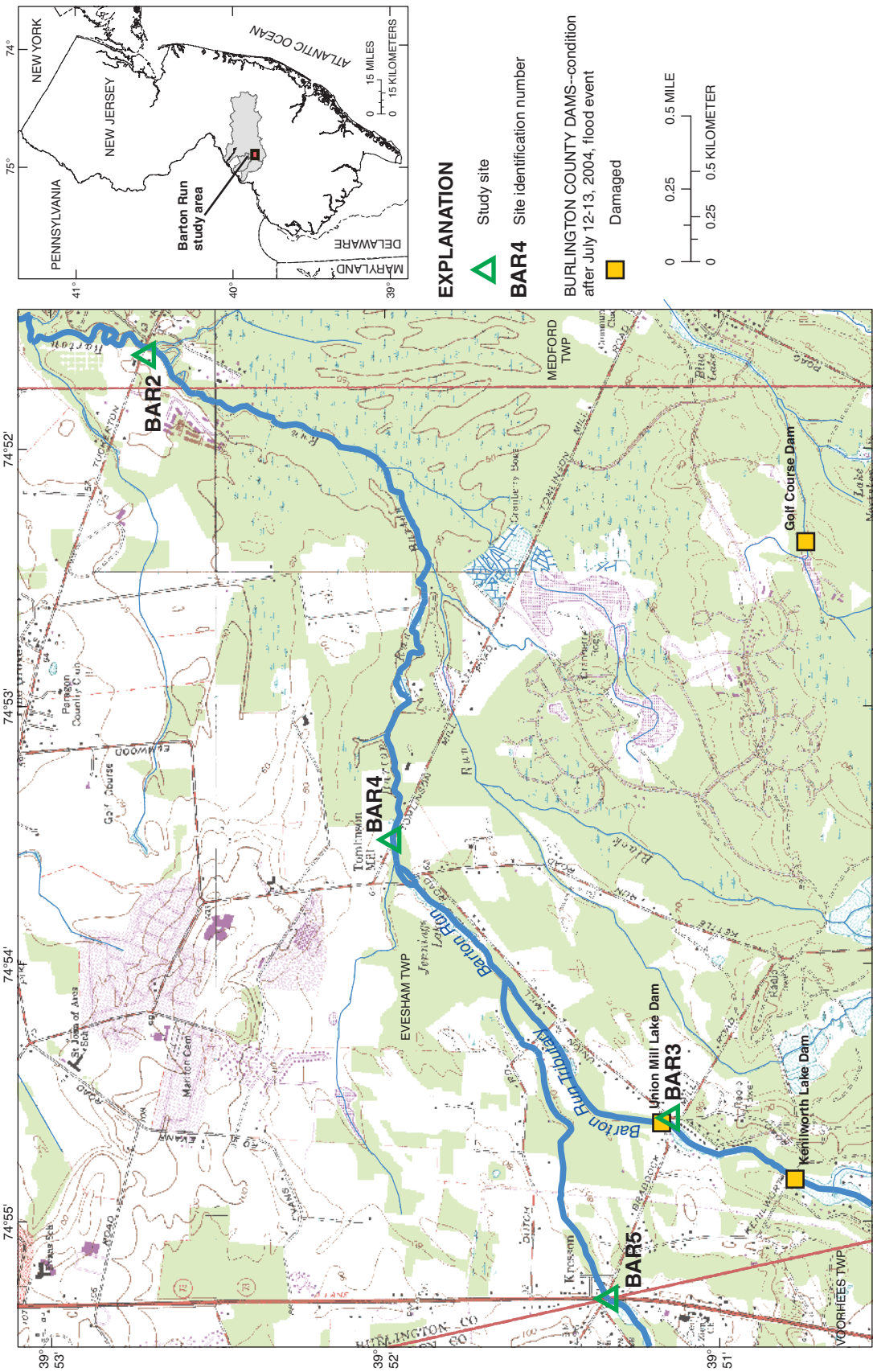


Location of Ballinger Run stream reach, study sites, precipitation gage with value, and dams associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-6—Continued.

| Ballinger Run (tributary to Haynes Creek) | | |
|---|------------------|---|
| Burlington County | Medford Township | <p>Site BAL7: (not an existing USGS station) Lat 39°50'46" Long 74°46'48", at Squaw Lake Dam in Medford Lakes, N.J. Medford Lakes USGS 7.5' Topographic Quadrangle High-Water Marks: one fair mark, 100 feet upstream on left bank; two good to fair marks, 30 and 50 feet downstream on right and left banks, respectively. Marks referenced to datum using Burlington County Engineering Department monument 7556.</p> |
| | | <p>Site BAL6: (not an existing USGS station) Lat 39°51'10" Long 74°47'25", at bridge on private road/Lake Stockwell dam in Medford Lakes, N.J. Medford Lakes USGS 7.5' Topographic Quadrangle High-Water Marks: one good mark, 75 feet upstream from dam on right bank; two fair to poor marks, 60 and 70 downstream of road on right and left banks, respectively. Marks referenced to datum using Burlington County Engineering Department monument 7556.</p> |
| | Medford Borough | <p>BAL5: (not an existing USGS station) Lat 39°51'27" Long 74°47'55", at Beach Drive/Upper Aetna Lake Dam in Medford Lakes, N.J. Medford Lakes USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 60 and 70 feet upstream from dam on right and left banks, respectively; one good mark, 60 feet downstream from road on left bank. Marks referenced to datum using RM4 from FEMA Flood Insurance Study, Borough of Medford Lakes (1980).</p> |
| | | <p>BAL4: (not an existing USGS station) Lat 39°51'57" Long 74°48'31", at bridge on Stokes Road (County Route 541) in Medford Lakes, N.J. Medford Lakes USGS 7.5' Topographic Quadrangle High-Water Marks: one good mark, 75 feet upstream on left bank; two good downstream marks, 50 and 75 feet downstream on right bank, respectively. Marks referenced to datum using RM4 from FEMA Flood Insurance Study, Borough of Medford Lakes (1980).</p> |
| | Medford Township | <p>Site BAL3: 01465876 Haynes Creek tributary 3 (Ballinger Run) at Fairview, N.J. Lat 39°52'02" Long 74°49'17", at bridge on Jackson Road/ Birchwood Lake Dam. Medford Lakes USGS 7.5' Topographic Quadrangle High-Water Marks: two good to poor marks, 75 feet upstream from dam, on left and right banks; two good marks, 100 feet downstream from road, on left and right banks. Marks referenced to datum using RM26 from FEMA Flood Insurance Study, Township of Medford (1983b).</p> |
| | | <p>Lat 39°52'15" Long 74°49'50", at bridge on Ramblewood Lane/Timber Lake Dam. Medford Lakes USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 200 and 300 feet upstream from dam on right and left banks, respectively. One good mark, 75 feet downstream from dam (not listed in table 4) at same elevation as marks upstream from dam. One good downstream mark (included in table 4), 400 feet downstream from dam on left bank. Marks referenced to datum using RM13 from FEMA Flood Insurance Study, Township of Medford (1983b).</p> |

Appendix 1-7

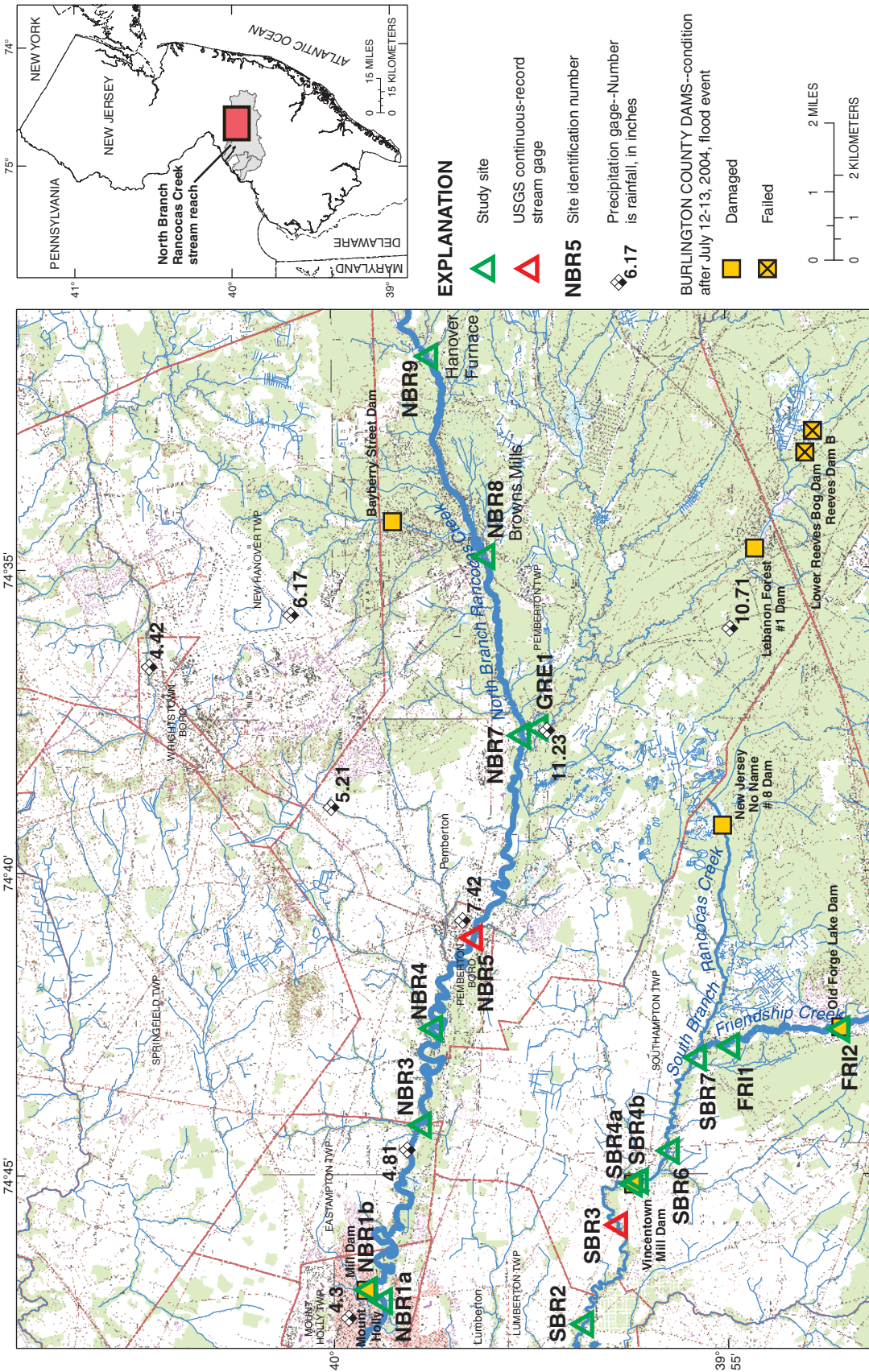


Location of Barton Run and Barton Run tributary stream reach, study sites, and dams associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-7—Continued.

| Barton Run and Barton Run tributary (tributary to Southwest Branch Rancocas Creek) | | |
|--|--------------------|---|
| Camden County | Voorhees Township* | <p>BAR5: 01465860 Barton Run at Braddock Road at Kresson, N.J. Lat 39°51'20" Long 74°55'18", at bridge on State Road 73/Union Mill Lake Dam, at outlet of Kresson Lake, in Kresson. *On boarder of Voorhees (upstream) and Evesham (downstream) Townships, Camden and Burlington Counties.FEMA Flood Insurance Study (FIS) of Evesham Township (1995) does not include this reach, which was noted in the FIS as an unnamed tributary. It is defined as Barton Run in the U.S. Department of Housing and Urban Development (HUD) Flood Insurance Study, Township of Vorhees (1978b). Clementon USGS 7.5' Topographic Quadrangle High-Water Marks: one fair mark, 20 feet upstream from dam on left bank; two marks, 40 feet downstream from road, on left and right banks. Marks referenced to datum using RM2 from HUD Flood Insurance Study, Township of Vorhees (1978b).</p> |
| Burlington County | Evesham Township** | <p>BAR4: (not an existing USGS station) Lat 39°51'59" Long 74°53'31", at bridge on Taunton Lake Road (County Route 544), downstream from Jennings Lake, in Tomlinson Mill, N.J. Clementon USGS 7.5' Topographic Quadrangle High-Water Marks: two good to fair marks, 30 and 35 feet upstream on left and right banks, respectively; two good marks, 15 and 30 feet downstream on right and left banks. Marks referenced to datum using RM13 from FEMA Flood Insurance Study, Township of Evesham (1995).</p> |
| | | <p>BAR3: BARTON RUN TRIBUTARY** (not an existing USGS station) Lat 39°51'09" Long 74°51'38", at bridge on Braddock Mill Road, downstream from Kennilworth Lake, west of Kresson, N.J. **Defined as Barton Run in the FEMA Flood Insurance Study, Township of Evesham (1995). High-Water Marks: two good marks, 60 and 90 feet upstream from dam/control structure, on left and right banks, respectively; two good marks, 60 feet downstream from Braddock Mill Road, on left and right banks, respectively. Marks referenced to datum using RM2 from HUD Flood Insurance Study, Township of Voorhees (1978b).</p> |
| | Medford Township | <p>BAR2: 01465865 Barton Run at Tuckerton Road near Medford, N.J. Lat 39°52'43" Long 74°51'38", at bridge on Tuckerton Road near Medford. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 45 and 60 feet upstream on left and right banks, respectively; two good marks, 80 and 100 feet downstream on left and right banks, respectively. Marks referenced to datum using RM37 from FEMA Flood Insurance Study, Township of Medford (1983b).</p> |

Appendix 1-8



Location of North Branch Rancocas Creek stream reach, study sites, precipitation gages with values, and dams associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-8—Continued.

| North Branch Rancocas Creek (tributary to Rancocas Creek) | | |
|---|---------------------|--|
| Burlington County | Pemberton Township | <p>NBR9: 01465950 North Branch Rancocas Creek at Hanover Furnace, N.J. Lat 39°58'46" Long 74°31'30", at bridge on Military Road, at outlet of Hanover Lake in Hanover Furnace. Browns Mills USGS 7.5' Topographic Quadrangle High-Water Marks: no upstream marks; one poor mark, 3 feet downstream from road on left bank. Marks referenced to datum using Cape Environmental/French & Parrello Associates Consulting Engineers benchmark BM-B.</p> |
| | | <p>NBR8: 01465970 North Branch Rancocas Creek at Browns Mills, N.J. Lat 39°58'04" Long 74°34'48", at Browns Mills Dam at Lakehurst Road (County Route 530), in Browns Mills. Browns Mills USGS 7.5' Topographic Quadrangle High-Water Marks: two good to fair marks, 100 feet upstream from dam; two excellent to good marks, 40 feet downstream from road. Marks referenced to datum using National Geodetic Survey monument 3J1 (PID: AB8732)</p> |
| | | <p>NBR7: 01465980 North Branch Rancocas Creek at New Lisbon, N.J. Lat 39°57'37" Long 74°37'46", at bridge on Springfield Road (County Route 646) in New Lisbon. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 80 feet upstream on left and right banks; two good marks, 20 and 40 feet downstream from dam/spillway, respectively. Marks referenced to datum using National Geodetic Survey monument X20 (PID: JU0635).</p> |
| | Pemberton Borough | <p>NBR5: 01467000 North Branch Rancocas Creek at Pemberton, N.J. (continuous-record gage) Lat 39°58'12" Long 74°41'05", at bridge on Hanover Street (County Route 616) and dam 500 feet downstream, in Pemberton. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 150 and 160 feet upstream from road on right and left banks, respectively; continuous gage, 20 feet downstream from road, recorded peak of 35.4 feet; one unrated mark, 500 feet downstream from dam on left bank. Marks referenced to datum using National Geodetic Survey monument 27380 (PID: AB6705).</p> |
| | Pemberton Township | <p>NBR4: 01467002 North Branch Rancocas Creek at Birmingham, N.J. Lat 39°58'44" Long 74°42'36", at bridge on Birmingham Road, in Birmingham. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 100 feet upstream on left and right banks; two fair to good marks, 10 and 80 feet downstream on right and left banks, respectively. Marks referenced to datum using RM2 from FEMA Flood Insurance Study, Township of Pemberton (1979a).</p> |
| | Eastampton Township | <p>NBR3: 01467003 North Branch Rancocas Creek at Ewansville, N.J. Lat 39°58'53" Long 74°44'11", at bridge on U.S. Route 206 in Ewansville. Pemberton USGS 7.5' Topographic Quadrangle High-Water Marks: two good upstream marks, 300 and 400 feet upstream on right and left banks, respectively; two good marks 300 feet downstream on left and right banks. Marks referenced to datum using New Jersey Geodetic Survey monument 11816.</p> |
| Mount Holly Township | | <p>NBR1b: (not an existing USGS station) Lat 39°59'34" Long 74°46'54", at Iron Works Dam in Mount Holly, N.J. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: five unrated marks, within 50 feet from upstream side of dam, on left and right banks; two unrated marks within 50 feet of downstream side of dam, on left and right banks. Marks referenced to datum using RM13 from HUD Flood Insurance Study, Township of Mount Holly (1979a).</p> |
| | | <p>NBR1a: 01467006 North Branch Rancocas Creek at Pine Street at Mount Holly, N.J. Lat 39°59'34" Long 74°46'54", at bridge on Pine Street in Mount Holly. Mount Holly USGS 7.5' Topographic Quadrangle High-Water Marks: one unrated mark on right upstream wingwall; two unrated marks on left and right downstream wingwalls. Marks referenced to datum using RM13 from FEMA Flood Insurance Study, Township of Mount Holly (1979a).</p> |

Appendix 1-8—Continued.



High-water mark on upstream, right bank of North Branch Rancocas Creek at Ewansville, N.J. (NBR3).



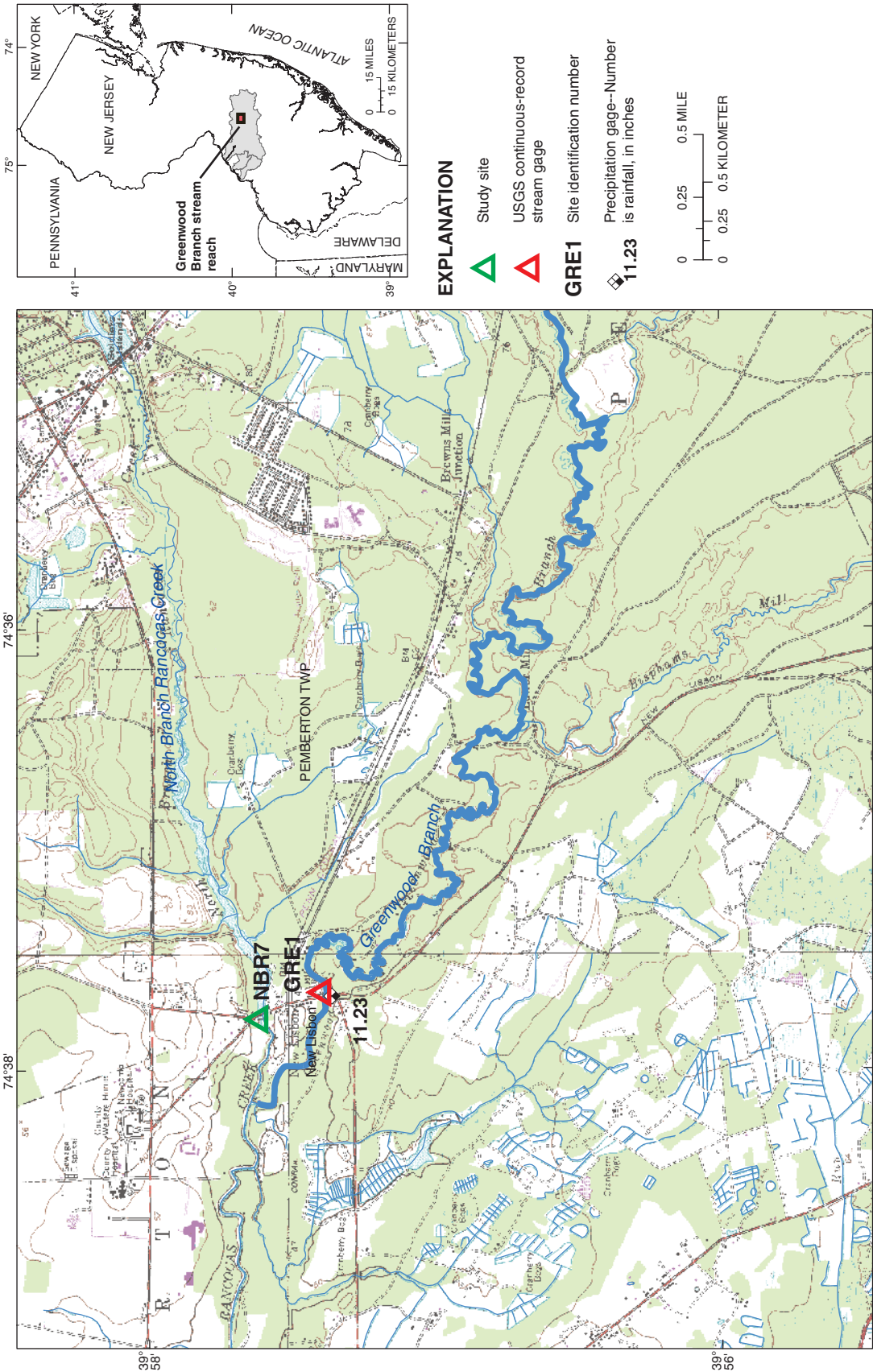
High-water mark on downstream, right bank of North Branch Rancocas Creek at Ewansville, N.J. (NBR3).

Appendix 1-8—Continued.



High-water mark in former gage house, 900 feet downstream from North Branch Rancocas Creek at Pemberton, N.J. (NBR5).

Appendix 1-9

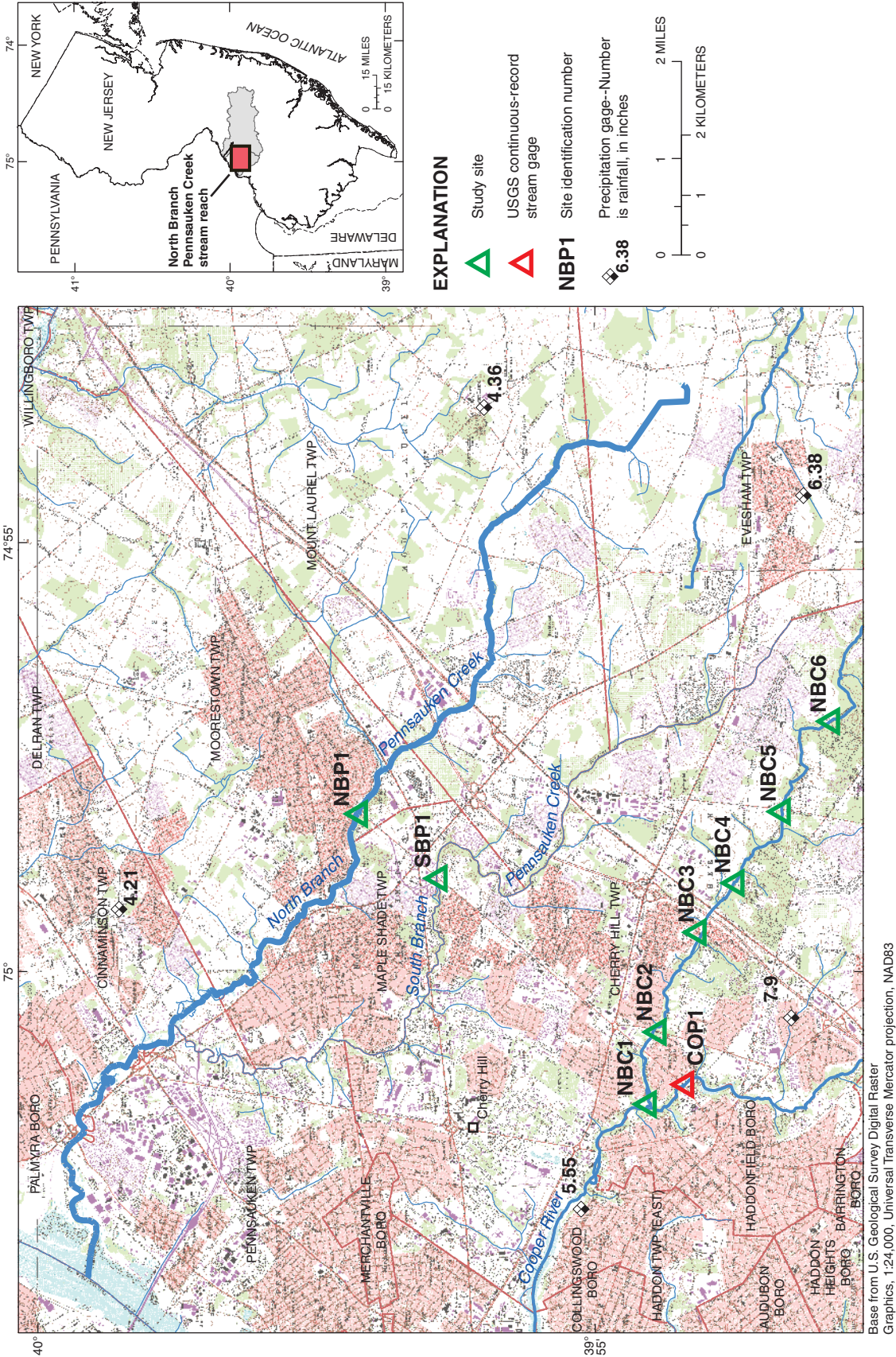


Location of Greenwood Branch stream reach, study sites, and precipitation gage with value associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-9—Continued.

| Greenwood Branch (tributary to North Branch Rancocas Creek) | | |
|---|--------------------|---|
| Burlington County | Pemberton Township | <p>GRE1: 01466900 Greenwood Branch at New Lisbon, N.J. (continuous-record gage) This stream is referred to as Mount Misery Creek in the FEMA Flood Insurance Study, Pemberton Township, (1979a). Lat 39°57'23" Long 74°37'39", at dam at bridge on Fourmile Road in New Lisbon. Pemberton USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: continuous gage, approximately 50 feet upstream from dam, recorded peak of 44.4 feet; one fair mark on upstream bridge face (same peak elevation as on gage above dam); one fair mark on downstream bridge face. Marks referenced to datum using National Geodetic Survey monument X20 (PID: JU0635).</p> |

Appendix 1-10



Location of North Branch Pennsauken Creek stream reach, study sites, and precipitation gages with values associated with the July 12-13, 2004, flood event, south-central New Jersey.

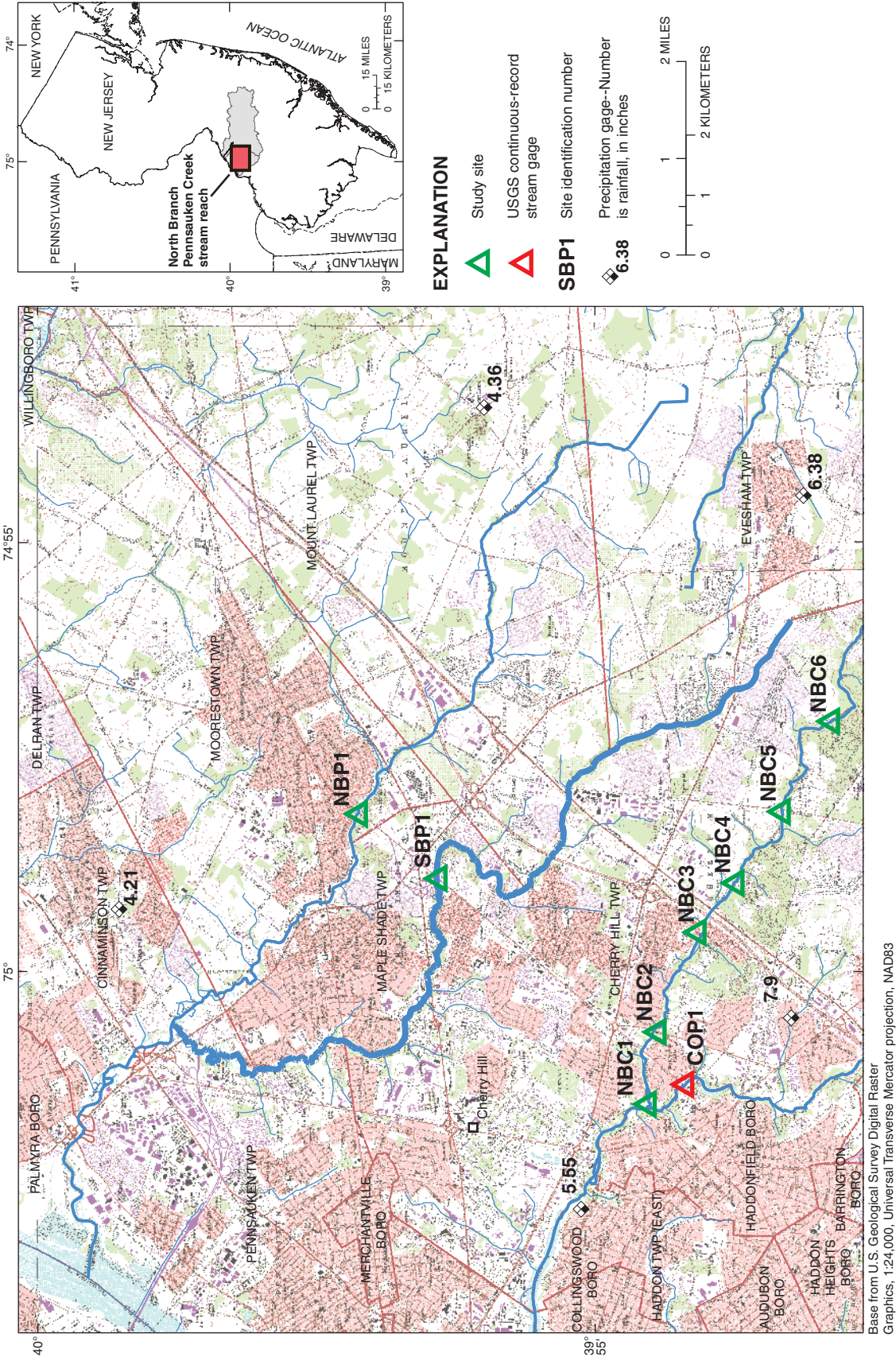
Appendix 1-10—Continued.

| North Branch Pennsauken Creek (tributary to Pennsauken Creek) | | |
|---|------------------------|--|
| Burlington County | Moorestown Township | <p>NBP1: 01467069 North Branch Pennsauken Creek near Moorestown, N.J. (crest-stage gage) Lat 39°57'07" Long 74°58'10", at bridge on Kings Highway, downstream from Strawbridge Lake outlet, near Moorestown. Moorestown USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: two good marks, 20 and 40 feet upstream from road, on right and left banks, respectively; two good marks, 50 and 60 feet downstream from road, on right and left banks, respectively. Marks referenced to datum using USGS station levels.</p> |



High-water mark on downstream right bank at North Branch Pennsauken Creek near Moorestown, N.J. (NBP1).

Appendix 1-11



Location of South Branch Pennsauken Creek stream reach, study sites, and precipitation gages with values associated with the July 12-13, 2004, flood event, south-central New Jersey.

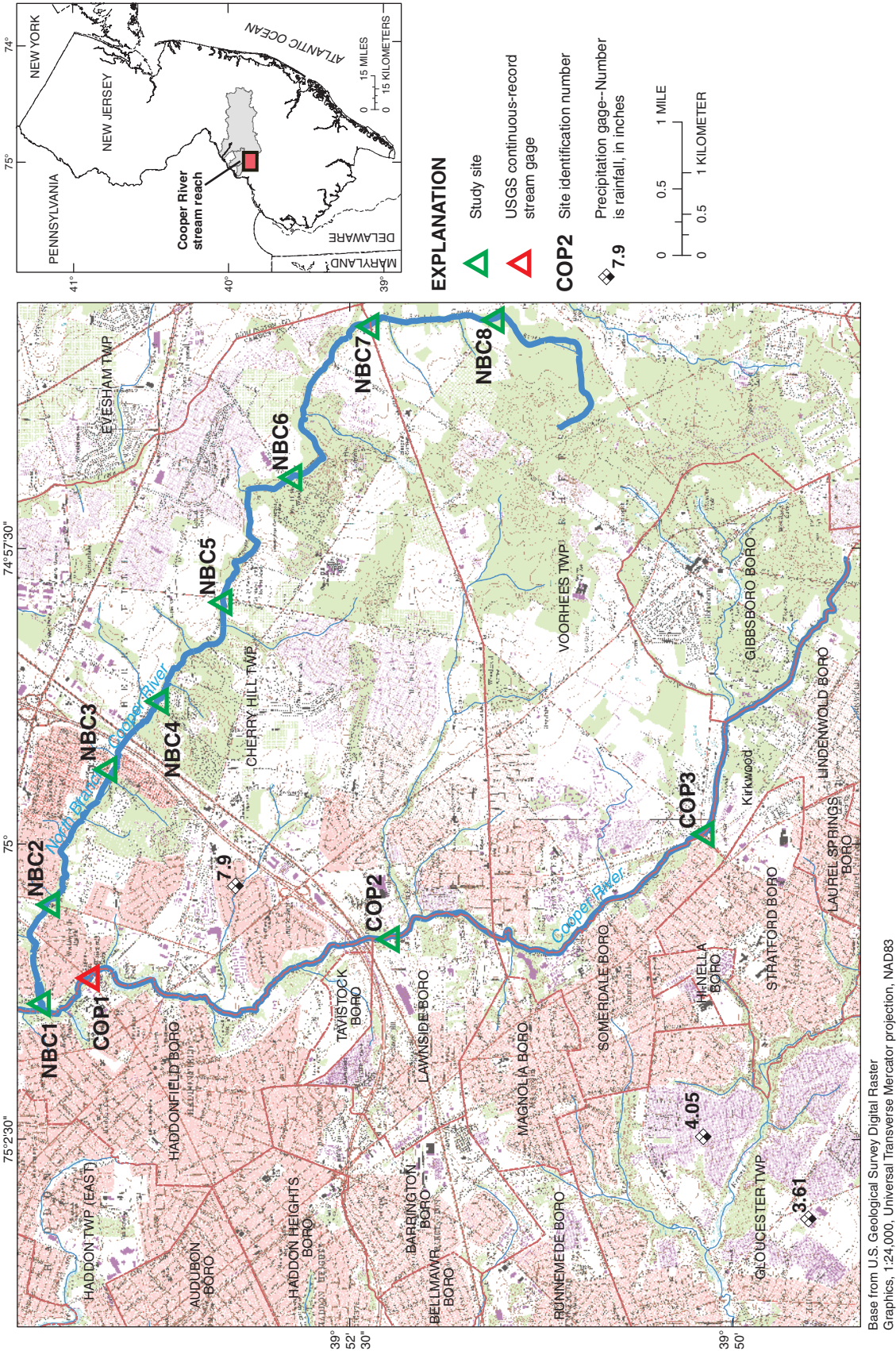
Appendix 1-11—Continued.

| South Branch Pennsauken Creek (tributary to Pennsauken Creek) | | |
|---|----------------------|---|
| Camden County | Cherry Hill Township | SBP1: 01467080 South Branch Pennsauken Creek at Maple Shade, N.J. Lat 39°56'25" Long 74°58'55", at bridge on Old Kings Highway (State Route 41), in Maple Shade. Moorestown USGS 7.5' Topographic Quadrangle High-Water Marks: two fair to good marks, 60 and 80 feet upstream on left and right banks, respectively; one fair mark, 90 feet downstream on left bank. Marks referenced to datum using USGS station levels. |
| | | SBP0: 01467081 South Branch Pennsauken Creek at Cherry Hill, N.J. (continuous-record gage) Lat 39°56'30" Long 74°00'04", at downstream side of bridge on Mill Road in Cherry Hill. Camden USGS 7.5' Topographic Quadrangle High Water Marks: none flagged. Crest-stage gage at site confirmed recorded peak. |



High-water mark on downstream left bank of South Branch Pennsauken Creek at Maple Shade, N.J. (SBP1).

Appendix 1-12



Location of Cooper River stream reach, study sites, and precipitation gages with values associated with the July 12-13, 2004, flood event, south-central New Jersey.

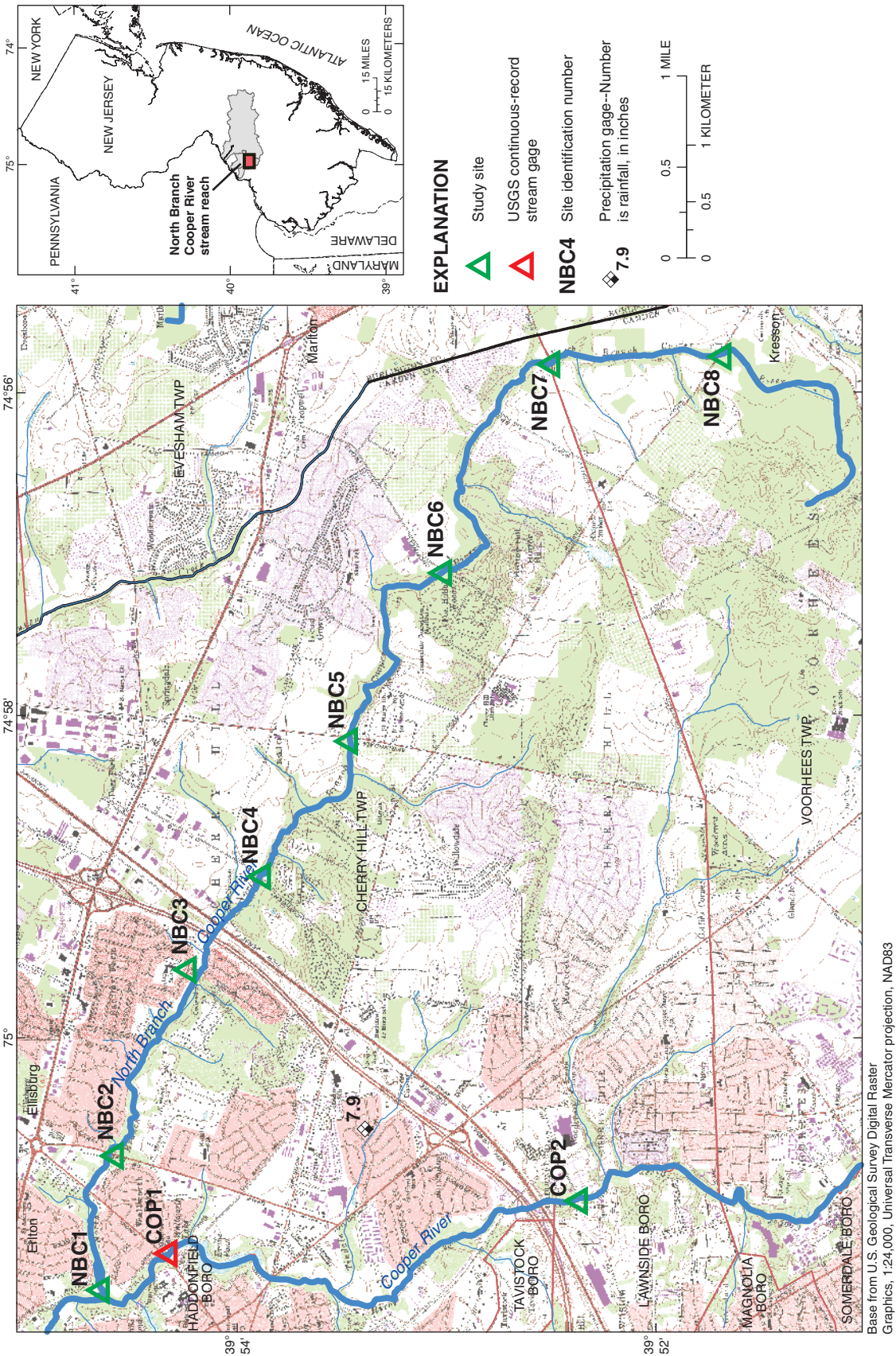
Appendix 1-12—Continued.

| Cooper River (tributary to Delaware River) | | |
|--|----------------------|--|
| Camden County | Voorhees Township | <p>COP3: 01467130 Cooper River at Kirkwood, N.J. (crest-stage gage) Lat 39°50'11" Long 75°00'06", at Kirkwood Lake dam, upstream from Whitehorse Road, in Kirkwood. Runnemedede USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: two fair marks, 40 and 50 feet upstream from dam, on right and left banks, respectively; two fair marks, 100 feet downstream from dam, between Kirkwood Lake bridge and Whitehorse Road. Marks referenced to datum using USGS station levels.</p> |
| | Lawnside Township | <p>COP2: 01467140 Cooper River at Lawnside, N.J. (crest-stage gage) Lat 39°52'14" Long 75°00'59", at bridge on Melrose Avenue in Lawnside. Runnemedede USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: one fair mark, 60 feet upstream on right bank; one good mark 70 feet downstream on right bank. Marks referenced to datum using RM1 from HUD Flood Insurance Study, Township of Lawnside (1978a).</p> |
| | Haddonfield township | <p>COP1: 01467150 Cooper River at Haddonfield, N.J. (continuous-record gage) Lat 39°54'11" Long 75°01'19", at bridge on Kings Highway (State Highway 41). Continuous-record gage (01467150) is 150 feet upstream from road, above dam. Camden USGS 7.5' Topographic Quadrangle</p> <p>High-Water Marks: a total of 34 marks were flagged from 100 feet upstream from the dam, to 350 feet downstream from Kings Highway, for indirect computation of discharge. Continuous-record gage (01467150) recorded a peak of 15.56 feet. Elevations given in table 4 represent peak elevations between footbridges and Kings Highway on the upstream and downstream sides, respectively.</p> |



Footbridge, on the upstream side of Kings Highway, over the Cooper River at Haddonfield, N.J. (COP1), during the recession of the flood (July 13, 2004).

Appendix 1-13



Location of North Branch Cooper River stream reach, study sites, and precipitation gage with value associated with the July 12-13, 2004, flood event, south-central New Jersey.

Appendix 1-13—Continued.

| North Branch Cooper River (tributary to Cooper River) | | |
|---|----------------------|--|
| Camden County | Voorhees Township | <p>NBC8: 01467155 North Branch Cooper River at Kresson, N.J. Lat 39°51'33" Long 74°55'45", at bridge on Kresson Road in Kresson. Clementon USGS 7.5' Topographic Quadrangle High-Water Marks: two fair marks, 15 and 20 feet upstream on left and right banks, respectively; two fair marks, 20 feet downstream on left and right banks, respectively. Marks referenced to datum using RM7 from HUD Flood Insurance Study, Township of Voorhees (1978b).</p> |
| | | <p>NBC7: (not an existing USGS station) Lat 39°52'22" Long 74°55'48", at bridge on Evesham road near Haines Corner, N.J. Clementon USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 80 and 90 feet upstream on right and left banks, respectively; two flood marks, 60 and 70 feet downstream on left and right banks, respectively. Marks referenced to datum using National Geodetic Survey monument 15918 (PID: AB8738).</p> |
| | Cherry Hill Township | <p>NBC6: (not an existing USGS station) Lat 39°52'53" Long 74°57'05", at bridge on Cropwell Road in Fox Hollow Woods, N.J. Moorestown USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 25 and 50 feet upstream on left and right banks, respectively; two good marks, 25 and 70 feet downstream on right and left banks, respectively. Marks referenced to datum using RM7 from HUD Flood Insurance Study, Township of Voorhees (1978b).</p> |
| | | <p>NBC5: 01467160 North Branch Cooper River near Marlton, N.J. (crest-stage gage) Lat 39°53'20" Long 74°58'08", at bridge on Springdale Road, south of Springdale. Moorestown USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 10 and 35 feet upstream on right and left banks, respectively; one good mark, 90 feet downstream on right bank. Marks referenced to datum using RM7 from HUD Flood Insurance Study, Township of Voorhees (1978b).</p> |
| | | <p>NBC4: (not an existing USGS station) Lat 39°53'45" Long 74°58'58", at bridge on Marl-kress (Cuthbert) Road near Springdale, N.J. Moorestown USGS 7.5' Topographic Quadrangle High-Water Marks: two good marks, 80 and 90 feet upstream on right and left banks, respectively; one good mark, 60 feet downstream on right bank. Marks referenced to datum using RM7 from HUD Flood Insurance Study, Township of Voorhees (1978b).</p> |
| | | <p>NBC3: (not an existing USGS station) Lat 39°54'06" Long 74°59'33", at bridge on Covered Bridge Road in Barclay Farm, N.J. Moorestown USGS 7.5' Topographic Quadrangle High-Water Marks: three good to fair marks, 10 to 100 feet upstream on right on left banks, respectively; two good marks, 15 feet downstream on right and left banks. Marks referenced to datum using RM7 from HUD Flood Insurance Study, Township of Voorhees (1978b).</p> |
| | | <p>NBC2: 01467180 North Branch Cooper River at Ellisburg, N.J. (crest-stage gage) Lat 39°54'27" Long 75°00'42", at bridge on Brace Road in Ellisburg. Camden USGS 7.5' Topographic Quadrangle High-Water Marks: three good to fair marks, 70 feet upstream on left and right banks; five good to fair marks, within 100 feet downstream from road, on left and right banks.</p> |
| | | <p>NBC1: 01467181 North Branch Cooper River at Erlton, N.J. Lat 39°54'31" Long 75°01'32", at bridge on Bark Boulevard in Erlton. Camden USGS 7.5' Topographic Quadrangle High-Water Marks: four fair marks, 40 to 100 feet upstream on right and left banks; three good to fair marks, 90 to 160 feet downstream on right and left banks. Marks referenced to datum using RM4 from FEMA Flood Insurance Study, Township of Cherry Hill (1992a).</p> |

Appendix 1-13—Continued.



High-water mark on the downstream right bank of the North Branch Cooper River at Ellisburg, N.J. (NBC2).

Appendix 2—Selected photographs of high-water marks and post-flood stream conditions in the study area

(All photographs taken by USGS field crews)

Appendix 2—Selected photographs of high-water marks and post-flood stream conditions in the study area

South Branch Rancocas Creek



Site SBR0. Line painted on boat ramp (by unknown source) marking approximate crest of flood on the upstream right bank of the South Branch Rancocas Creek on Marne Highway (County Route 537) in Rancocas Heights, N.J. Photograph taken on August 10, 2004.



Site SBR4a. High-water mark on tree, downstream from Church Road (County Route 616) in Vincentown, N.J., on the right bank of the South Branch Rancocas Creek. Photograph taken on July 21, 2004.

South Branch Rancocas Creek—Continued



ite SBR3. Flow over Landing Street (County Route 641) in Vincentown, N.J. during recession of the flood. Photograph taken on July 13, 2004.

Friendship Creek



Site FRI3. High-water mark, downstream from State Route 70 on the right bank of Friendship Creek between Friendship and Red Lion, N.J. Photograph taken on July 23, 2004.



Site FRI6. Looking downstream at remnants of Middle Innawendiwin Dam on Friendship Creek in Friendship, N.J. Photograph taken on July 28, 2004.

Haynes Creek



Site HAY1. High-water mark on Mimosa tree on downstream right bank of Haynes Creek at Himmelein Road in Oliphants Mills, N.J. Photograph taken on July 22, 2004.

Haynes Creek—Continued



Site HAY4. USGS Survey Marker indicating seed line on tree, 500 feet downstream from Centennial Dam Road near Medford Lakes N.J., on the right bank of Haynes Creek. Photograph taken on July 22, 2004.

Southwest Branch Rancocas Creek



Site SWB4. High-water mark on garage on downstream left bank at Main Street bridge in Medford, N.J. Photograph taken on July 16, 2004. Ballinger Run.

Ballinger Run



Site BAL3. Flood damage at the Jackson Road bridge over Ballinger Run in Medford Lakes, N.J. Dam upstream failed. Photograph taken on July 22, 2004.



Site BAL5. Failed dam at Upper Aetna Lake on Beach Drive in Medford Lakes, N.J. Photograph taken July 21, 2004.

Barton Run



Site BAR3. High-water mark on bulkhead pilings on the upstream, right bank of Barton Run at Braddock Mill Road in Kresson, N.J. Photograph taken on July 23, 2004.

North Branch Rancocas Creek



Site NBR5. High-water mark on tree in foreground and the North Branch Rancocas Creek flowing over the dam in the background near Hanover Street in Pemberton, N.J. Photograph taken on July 21, 2004

North Branch Pennsauken Creek



Site NBP1. High-water mark on tree, at upstream side of Kings Highway, on left bank of the North Branch Pennsauken Creek in Moorestown, N.J. Photograph taken on August 2, 2004.

South Branch Pennsauken Creek



Site SBP1. High-water mark at top of right bank of the South Branch Pennsauken Creek, upstream of Kings Highway in Maple Shade, N.J. Photograph taken August 2, 2004.

Cooper River



Site COP1. High-water mark on left bank, downstream from dam on Cooper River, upstream from Kings Highway (State Route 41) in Haddonfield, N.J. Photograph taken July 14, 2004.

North Branch Cooper River



Site NBC4. High-water mark on tree, upstream side of Markkress Avenue on left bank of the North Branch Cooper River in Springdale, N.J. Photograph taken July 22, 2004.

For additional information, write to:
Director
U.S. Geological Survey
New Jersey Water Science Center
Mountain View Office Park
810 Bear Tavern Rd., Suite 206
West Trenton, NJ 08628

or visit our Web site at:
<http://nj.usgs.gov/>

Protz, A.R. and Reed, T.J.—**FLOOD OF JULY 12-13, 2004, BURLINGTON AND CAMDEN COUNTIES, SOUTH-CENTRAL NEW JERSEY**—
Scientific Investigations Report 2006-5096